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Acupuncture effects on delayed onset muscle soreness

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ACUPUNCTURE EFFECTS ON DELAYED ONSET MUSCLE SORENESS

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Resumo

Introdução: Apesar de haver vários estudos sobre a sensação retardada de desconforto muscular (SRDM), a explicação dos mecanismos referentes a esta condição clínica ainda se encontra em discussão, assim como as suas estratégias de tratamento e prevenção. Os estudos científicos mostram que não há consenso sobre os efeitos da acupunctura na SRDM.

Objectivo: Avaliar os efeitos da acupunctura na SRDM.

Métodos: 45 participantes (média ± s idade 25,38 ± 4,77 anos; peso 65,76 ± 9,88 kg; altura 169 ± 0,09 cm e índice de massa corporal 22,94 ± 2,51 kg/m^2) dos dois géneros (19 homens, 26 mulheres), depois de completarem um questionário de triagem e fornecerem o consentimento informado escrito, foram distribuídos de forma aleatória em três grupos (grupo de acupunctura verdadeira, grupo de acupunctura falsa e grupo controlo – AV, AF e GC). O desconforto muscular (DM), limiar de dor à pressão (LDP), amplitude articular (AA), salto vertical (SV) e avaliações do isocinético foram realizados antes e após (imediatamente e 24h) um protocolo de exercícios de dano muscular (EDM) em que os indivíduos realizaram cinco séries de 20 *drop jumps* num *step* a uma altura de 0,6m, com 10 segundos de intervalo entre saltos e 2 minutos de descanso entre séries. A análise estatística foi realizada através do Microsoft Excel 2010, para determinar a média e desvio padrão da amostra e dos parâmetros avaliados, e o IBM SPSS Statistics 22 foi usado para realizar o teste Kruskal-Wallis para a análise das diferenças entre grupos em diferentes momentos e bem como para o Teste de Friedman com o Teste Bonferroni post-hoc, para obter as diferenças entre grupos ao longo dos diferentes momentos.

Resultados: O protocolo de EDM foi bem sucedido ao induzir SRDM. Quando os grupos de AV, AF e GC foram comparados, verificou-se que a AV teve melhores resultados em todos os parâmetros avaliados, especialmente no DM, LDP e SV. Contudo, o grupo de AF demonstrou melhores resultados que o GC, quando o DM e LDP foram comparados, mas não foram resultados com diferença estatisticamente significativa.

Conclusão: Os resultados demonstram que, a acupunctura aplicada depois de um protocolo de EDM, teve efeitos de redução do DM e melhoria no LDP, AA, SV e medições no isocinético.

Palavras-Chave: Acupunctura, Medicina Tradicional Chinesa, sensação retardada de desconforto muscular, exercícios de dano muscular.

Abstract

Introduction: Despite of the many studies on the subject of delayed onset muscle soreness (DOMS), the explanation of the mechanisms underlying this clinical condition is still under discussion, as well as the strategies for its prevention and treatment. Scientific studies have shown no consensus of the effects of acupuncture on DOMS.

Objective: To evaluate acupuncture effects on DOMS.

Methods: 45 participants (mean ± s age 25,38 ± 4,77 years; weight 65,76 ± 9,88 kg; height 169 ± 0,09 cm and body mass index 22,94 ± 2,51 Kg/m^2) of both genders (19 males, 26 females), after completing a screening questionnaire and providing written informed consent, were randomly distributed into three groups (verum acupuncture group, sham acupuncture group and a control group – VA, SA and CG) . Muscle soreness (MS), pressure pain threshold (PPT), range of motion (ROM), vertical jump (VJ) and Isokinetic evaluations were performed before and after (immediately and 24h) a exercise induced muscle damage (EIMD) protocol which subjects performing a five sets of 20 drop jumps from a height of 0,6m step, with a 10 seconds interval between jumps and 2 minutes rest period between sets. Statistical analysis was performed using Microsoft Excel 2010 to determine the mean and standard deviations of the sample and outcome measures, and IBM SPSS Statistics 22 was used to perform a Kruskal-Wallis test with for analysis of differences between groups in the different moments and a Friedman test with a Bonferroni post-hoc test, to assess differences within the group along the different moments.

Results: The protocol of EIMD showed success in inducing DOMS. When VA, SA and CG groups were compared, it was found that VA had better results in all outcome measures, especially in MS, PPT and VJ. However, SA group showed better results than CG, when MS and PPT were compared, but they were not statistically significant.

Conclusion: The results showed that acupuncture applied after an EIMD protocol, had an effect on MS reduction and an improvement on PPT, ROM, VJ and Isokinetic measures.

Key words: Acupuncture, Traditional Chinese Medicine, delayed onset muscle soreness, exercise induced muscle damage.

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LIST OF ABBREVIATIONS

EIMD	Exercise-induced muscle damage
DOMS	Delayed Onset Muscle Soreness
RBE	Repeated-bout effect
MVC	Maximal Voluntary Contraction
ROM	Range of Motion
CK	Creatine kinase
LDH	Lactate dehydrogenase
MRI	Magnetic Resonance Imaging
US	Ultrasound
CNS	Central nervous system
LFF	Low frequency fatigue
HFF	High frequency fatigue
SR	Sarcoplasmic reticulum
EE	Eccentric exercise
ATP	Adenosine triphosphate
ROS	Reactive Oxygen Species
O2	Oxygen
EPOC	The over consumption of oxygen post-exercise
HMB	Beta-hydoxy-beta-methylbutyrate
TCM	Traditional Chinese Medicine
VA	Verum acupuncture group
SA	Sham acupuncture group
CA	Control acupuncture group
VAS	Visual analogue scale
PT	Peak torque
PT/BW	Peak torque/body weight
AVG PT	Average peak torque
BMI	Body mass index
MS	Muscle soreness
PPT	Pressure pain threshold
ROM	Range of Motion
VJ	Vertical Jump

Chapter 1 - Introduction

Introduction

Delayed onset muscle soreness (DOMS) is a common form of muscle soreness, experienced by individuals who perform unaccustomed exercise and consequently exercise induced muscle damage (EIMD), that typically involves an eccentric component that peaks between 24 and 48 hours post-exercise and that spontaneously disappears within 5 to 7 days (Aminian-Far et al., 2011; Torres et al., 2012).

However, it is not just novel strength training exercises or eccentric contractions that can cause DOMS. In the working environment, a common problem is muscle tenderness, soreness and pain, especially for workers frequently exposed to unilateral high repetitive movement's tasks (Andersen, Hansen, Mortensen, Zebis, 2011). Furthermore, as muscle pain has been associated with decreased performance in the form of decreased rapid force capacity and maximal muscle strength, continuous overload causing muscle soreness and pain may not only have adverse functional implications during working hours but also during activities of daily living during non-working hours (Andersen, Holtermann, Jørgensen, Sjøgaard, 2008; Andersen, Nielsen, Søgaard, Andersen, Skotte, Sjøgaard, 2008).

Acupuncture has shown to increase of muscular power (Huang, et al., 2007; Hubscher, et al., 2010; Ozerkan, et al., 2007; Yang, et al., 2006; Zhou, et al., 2012), to improve microcirculation (Kuo, Lin, Ho, 2004), to decrease inflammatory processes (Moon et al, 2007), to release endogenous endorphins (Hwang et al, 2002), to inhibit spinal and supraspinal nociceptive transmission (Ikeda, Asai, Murase, 2000; Rong et al, 2005), as well as to improve vertical jump (Sousa, 2012).

Therefore, from a theoretical standpoint, acupuncture might be an attractive, beneficial, low-cost, quick and low-risk treatment strategy for DOMS treatment, improving performance on athletes and productivity in workers.

The major aim of this thesis is to evaluate the effects of acupuncture on DOMS.

To fulfill this goal is presented a theoretical background data based on an extensive literature research with the intention to support the following experimental study.

The theoretical fundamentals are presented in the first part of the thesis (*chapter one*) which is comprised of a review on EIMD, DOMS, it´s physiology, consequences, factors that influence and models to induce DOMS. It´s prevention and treatment strategies are presented followed by an explanation of the Heidelberg Model of Traditional Chinese Medicine and neurophysiological basis of acupuncture.

The theoretical fundamentals are expected to provide the needed support for the following detailed description of the methods (chapter two). In the third chapter are exposed the results and in the chapter four are presented the discussion, that is supported by literature findings, the limitations and suggestions. Finally, the thesis is enclosed with the conclusions (chapter five).

1. Exercise induced muscle damage

In the early 1900's Dr. Theodore Hough observed a long lasting decline in force production and increased soreness following an exercise of the finger flexors (Hough, 1900), but only in the early 1980's, research on this exercise-induced muscle damage (EIMD) really begun (Thiebaud, 2012).

Unaccustomed muscle work, especially that which is eccentric in nature, can cause post-exercise soreness, usually referred to as delay onset muscle soreness (DOMS) (Lewis, Ruby, Bush-Joseph, 2012; Proske, Morgan, 2001; Yu, Malm, Thornell, 2002; Zainuddin, Newton, Sacco, Nosaka, 2005). Muscle soreness can negatively interfere with the activities of daily living as well as sports performance. Research commonly suggests that DOMS is the result of an inflammatory process caused by micro-tears in the muscle fibers during unaccustomed repetitive activity and/or eccentric contractions (Barbe, Barr, 2006; Barr, Barbe, Clark, 2004) but it has also been suggested that muscle soreness can occur without micro-trauma (Zainuddin, Newton, Sacco, Nosaka, 2005).

However, it is not just unaccustomed strength training exercises or eccentric contractions that can cause muscle soreness. In the working environment, a common problem is muscle tenderness, soreness and pain, especially for workers frequently exposed to unilateral high repetitive movements tasks. As an example, computer workers commonly experience soreness of several different neck/shoulder muscles (Andersen, Hansen, Mortensen, Zebis, 2011). Andersen and coworkers reported that 33% and 29% of blue and white-collar workers respectively, within the general working population, suffered from neck/shoulder pain (Andersen, Mortensen, Hansen, Burr, 2011). Furthermore, it seems that highly repetitive movement tasks can physically alter the muscle fiber itself. In a study of Andersen, Suetta, Andersen, Kjaer and Sjøgaard (2008), they identified grossly hypertrophied type 1 muscle fibers with poor capillarization – so called megafibers - in the trapezius muscle of women with trapezius myalgia who worked in monotonous jobs, indicating that high intensity or eccentric muscle contractions are not a prerequisite to cause muscle soreness. Furthermore, as muscle pain has been associated with decreased performance in the form of decreased rapid force capacity and maximal muscle strength, continuous overload causing muscle soreness and pain may not only have adverse functional implications during working hours but also during activities of day-to-day living (Andersen, Holtermann, Jørgensen, Sjøgaard, 2008; Andersen, Nielsen, Søgaard, Andersen, Skotte, Sjøgaard, 2008).

Figure 1 outlines the possible mechanisms of muscle damage. Several events happen to induce muscle damage. Specifically, the type of exercise producing the damage seems to be particularly important, as lengthening contractions tend to produce the greatest amount of muscle damage.

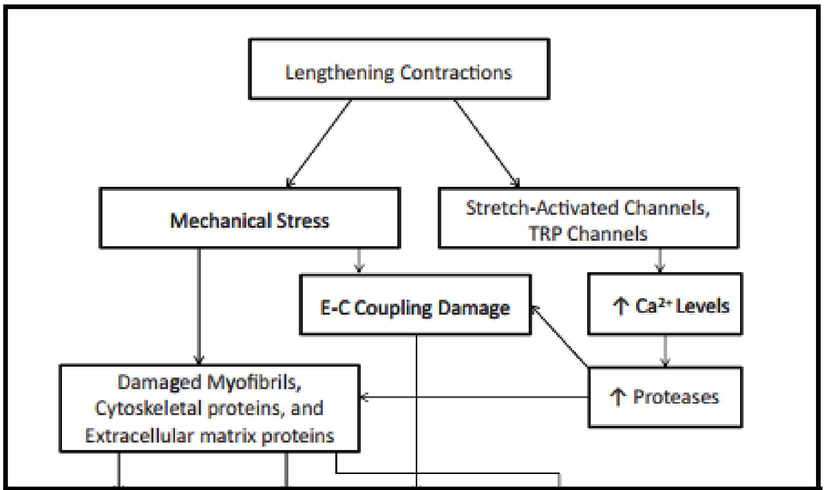


Figure 1 – Possible Mechanisms of Exercise Induced Muscle Damage. E-C coupling= Excitation-contraction coupling. TRP= Transient receptor potential (Thiebaud, 2012).

It was noted by Newham et al. (1983) that little damage was caused by shortening contractions but significantly greater damage was found in muscles performing lengthening contractions. In addition, maximal isometric contractions performed at 90 degrees elbow flexion produce no muscle damage (Nosaka, Newton, Sacco 2002) but when they are performed at longer muscle lengths (20 degrees elbow flexion) muscle damage occurs (Philippou et al., 2004). Thus, it seems that the initial event producing muscle damage results from mechanical overload to the muscle fiber when it contracts at long muscle lengths or during lengthening, eccentric contractions. Mechanical factors that contribute to the amount of EIMD include the number of contractions, force, specific force, and contraction velocity. As the number of lengthening contractions increase, a greater amount of EIMD is found (Talbot, Morgan, 1998). Force and specific force are particularly important factors producing EIMD. For example, McCully and Faulkner (1986) found that decreases in maximum isometric force were highly correlated with histological muscle damage and that this injury was related to the amount of peak force produced during eccentric contractions. Another study found that the peak total force produced during the eccentric contractions, decreased muscle performance independent of lengthening velocity or muscle length change (Warren et al., 1993). Lieber and Friden (1993) suggest that high forces did not necessarily dictate the amount of muscle damage produced but rather it was the muscle fiber strain produced during the lengthening contractions. In addition, they observed that faster lengthening velocities produced more muscle damage than slower velocities. Another study reported that higher specific torque eccentric contractions resulted in greater amounts of muscle damage compared to lower specific torque eccentric contractions when matching contraction velocity range of motion, active muscle, and contraction number (Black et al., 2008). All of these studies indicate that mechanical factors play a role in EIMD, and the mechanical damage produced by these factors translates into damage at the muscle fiber level.

Normally, EIMD results in symptoms such as DOMS, tenderness, edema, and muscle stiffness.

2. Delayed Onset Muscle Soreness

DOMS is classified as a type I muscle strain injury (Gulick, Kimura, 1996; Safran, Seaber, Garrett, 1989) which the main symptoms are tenderness and/or stiffness to palpation and/or movement (Gulick, Kimura, 1996). Although the pathology associated with DOMS is usually subclinical (Armstrong, Warren, 1993), the sensations experienced with this EIMD, can vary from slight muscle stiffness, which rapidly disappears during daily routine activities, to severe debilitating pain which restricts movement. Tenderness is usually concentrated in the distal portion of the muscle (Armstrong, 1984; Armstrong, Warren, 1993; Garrett, 1996; Garrett, 1990; MacIntyre, Reid, McKenzie, 1995; Noonan, Garrett, 1992) and becomes progressively diffuse in 24–48 hours post exercise (MacIntyre, Reid, McKenzie, 1995). This localization of pain can be attributed to a high concentration of muscle pain receptors in the connective tissue of the myotendinous region (Newham, Mills, Quigley, et al., 1982). The myotendinous junction is characterized by a membrane which is continuous, extensively folded and interconnected with the muscle cells (Noonan, Garrett, 1992). The oblique arrangement of the muscle fibers just prior to the myotendinous junction reduces their ability to withstand high tensile forces (Friden, Sfakianos, Hargens, 1986; Noonan, Garrett, 1992; Tidball, 1991). As a result, the contractile element of the muscle fibers in the myotendinous junction is vulnerable to microscopic damage. In table 1 are presented the clinical signs and symptoms of DOMS.

Table 1 - Clinical signs and symptoms of DOMS (Sethi, 2012).

Muscle soreness and aching peaks between 24 and 48 hours post-exercise and that spontaneously disappears within 5 to 7 days.
Tenderness with palpation throughout the involved muscle belly or at the myotendinous junction.
Increased soreness with passive lengthening or active contraction of the involved muscle.
Local edema and warmth.
Muscle stiffness reflected by spontaneous muscle shortening before the onset of pain.
Decreased range of motion during the time course of muscle soreness.
Deceased muscle strength prior to onset of muscle soreness that persists for up to 1 to 2 weeks after soreness has remitted.

2.1. Physiology of DOMS

DOMS is normally associated with unusual physical activities that develop large amounts of power (Cheung et al., 2003). The intensity level of discomfort rises within the first 24 hours, after the end of the activity, reaching the peak between 24 and 72 hours (Gleeson et al., 1998) and, depending on its severity level, it can last up to 10 days before it completely disappears (Cheung et al., 2003).

The origin of the muscular injury, associated with DOMS (Gleeson et al., 1998), has been the subject of a lot of research and theories. Clarkson and Sayers (1999), state that this damage is initiated by metabolic changes, followed by mechanical changes, causing inflammatory response and oxidative stress (Close et al., 2004).Other inflammatory mediators and the synthesis of acute phase proteins seem to have an important role on repairing this injury (Clarkson and Sayers, 1999). A schematic of the events associated with DOMS is presented in Figure 2.

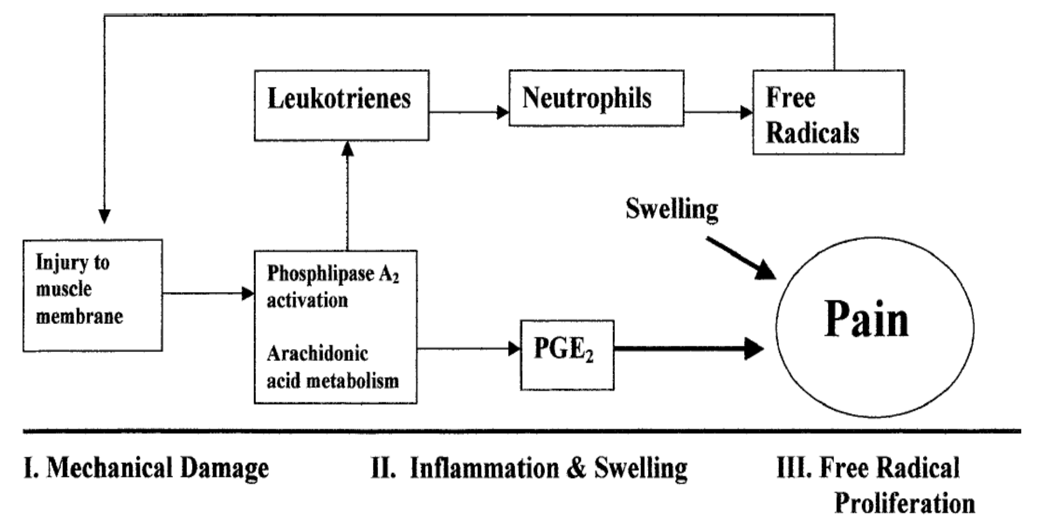


Figure 2 - Schematic showing possible sequence of injury in DOMS (Connolly, Sayers and Mchugh, 2003).

2.1.1. Mechanical Changes

2.1.1.1. Sarcomere Length

Studies show that are mainly the eccentric contractions the ones that cause this type of muscular damage (Hamill et al.,1991). In this type of contraction, the muscle stretches while exercising power, resulting on a tension and on a significantly bigger damage than in a concentric contraction (Clarkson and Sayers, 1999).

Morgan (1990), states that the muscular injury induced by the eccentric exercise (EE) is the result of a non-uniform length, by the sarcomeres when the activated muscle is stretched beyond its ideal length. So, if the sarcomeres are progressively stretched more than what they should be, they will become weaker decreasing their ability for force production (Morgan and Proske, 2004). Therefore, since the sarcomeres are not aligned throughout any myofibril, this non-uniform length causes a possible micro rupture of the myofibrils, exposing membranes and T tubules to big strains (Morgan and Proske, 2004).

The type I fibers (slow fibers) have a most robust structure unlike those of type II (fast fibers), which have weaker and narrower Z lines, becoming themselves more vulnerable to mechanical ruptures induced by stretching, and might cause more muscular pain in muscle with predominantly this type of fibers (Cheung et al., 2003).

After exercise the muscle suffers an adaptation phase. The Z line works as the origin to the formation of new sarcomeres and the continuous stretching of the muscular fibers during successive contractions (eccentrics) contributes to protein synthesis and muscular growth (Fridén, 1984). This author made a study where five subjects did a EE program during two months and checked that these stresses, when repeated for a long period, might induce structural changes on the muscular level, being able to create a reorganization of the muscular fibers which are the most affected, resulting in a better elasticity of those fibers, reducing the risk of mechanical injury throughout a better overlap between the actin and the myosin. As a result of this adaptation, when the muscular fibers are exposed to high stress, the sarcomeres are initially too much stretched out to develop this maximum stress, which causes more sarcomeres to be recruited, with a reduction on its length (Morgan, 1990).

2.1.1.2. Conjunctive tissue injury

Brown et al. (1997a), state that the muscular injury not only damages the muscular cells but there is also an increase of the collagen breakdown index on the days after EE, which indicates an injury on the connective tissue. According to Cheung et al. (2003), DOMS might be associated with the injury and the inflammation of the non-contracted connective tissue, which causes painful sensations when the muscle is palpated, stretched or activated.

Brown et al. (1997b) observed that, after having induced EE, the biggest perception of pain was on the distal portion of the muscle, extending itself up to the myotendinous junction and on the muscular belly the sensation was minimal. This junction has a membrane that is continuous, bended extensively and interdigitated with the muscular cells. The oblique disposition of the muscular fibers slightly before the myotendinous junction reduces its own capacity to resist to higher tensions, causing that the contracted elements of the muscular fibers of this junction are vulnerable to microscopic damages (Cheung et al., 2003).

2.1.1.3. Muscular spasm

Some studies verified an increase of the activity in muscular rest, which could indicate a tonic spasm of the motor units (Bobber et al.*cit. in* Cheung et al. 2003). Cheung et al. (2003) consider that it might lead to the compression of the blood vessels, ischemia and accumulation of painful substances, creating a vicious cycle, where a posterior stimulation of the nervous pain terminations might cause reflexive muscular spasms and prolonged conditions of ischemia.

2.1.2. Metabolic changes

2.1.2.1. Lactic acid

Gleeson et al. (1998), two days after having induced the DOMS through an EE, put the subjects of the experimental group on a cycloergometer starting at 150W, with increases of 50W, each 2 minutes, until fatigue. They verified a significant increase of the lactate concentration on the blood, which they connected with the increase of the glycogenesis due to an increase of the type II fibers recruiting. According to Powers and Howley (2000), the lactic acid production has been considered as an indication of increase on the anaerobic metabolism of the muscle that is being contracted, due to low levels of oxygen (O_2) (hypoxia) on the muscular cells. They also refer that, one of the hypothesis for the accumulation of lactic acid is due to the speed of the exercise, which causes an increase of adrenaline and noradrenaline levels, from 50-60% of the maximum VO_2, stimulating the glycolytic task and, therefore, the lactic acid production. Another explanation is associated with type II fibers recruitment on an intense and fast exercise, which promotes the lactate dehydrogenase isoenzyme affinity to pyruvic acid and thus increasing the formation of lactic acid. The muscular pain resulting from EE might also induce an increase of the muscular membrane permeability, creating an increase of lactic flux (Gleeson et al., 1998). On a muscular injury, after EE, the capacity to generate power might be compromised and, to maintain the power level, there will be an increment of a metabolic effort to excessively request fibers that, in a reduced number, aren't damaged (Gleeson et al., 1998). However, this metabolic toxic final product doesn't appear to be related with DOMS, because these lactic acid levels return to the values of a pre-exercise phase within an hour post-exercise (Cheung et al., 2003). Thus, lactic acid contributes to the muscular fatigue felt right after the exercise (Powers and Howley, 2000) but doesn't contribute to the DOMS felt between 24-48 hours post- exercise (Croisier et al., 2003).

2.1.2.2. Enzymatic flux

2.1.2.2.1. Creatine Kinase (CK)

The CK is an intramuscular enzyme responsible for the appropriate maintenance levels of adenosine triphosphate (ATP) during a muscular contraction (Fridén and Lieber, 2001). We can find it on the skeletal and cardiac muscle and is a reliable indicator of the muscular membrane permeability or sarcoplasmmatic reticulum (SR) (Cheung et al., 2003).

Numerous studies associate CK values with the magnitude of the muscular injury, although this correlation isn't necessarily proved. Cheung et al. (2003), refer that the CK values under normal conditions are around 100 IU/L, but only 12h after EE rupture of the Z lines and damages on the sarcolemma, and an increase of muscular cell membrane permeability is observed. This allows a diffusion of soluble muscular enzymes, like CK, to the interstitial fluid, increasing, thus, its values to 40000 IU/L. Despite that, discrepancy between the peak of the CK values (5 days post-exercise) and the muscular pain peak doesn´t explain the pain resulting from DOMS.

2.1.2.2.2. Calcium homeostasis

Calcium (Ca^{2+}) is usually stored on the SR (Powers and Howley, 2000). Damages on this structure and on its permeability, previously referred, will also increase the amount of intracellular Ca^{2+} due to its storage at the mitochondrial level (Clarkson and Sayers, 1999).

Clarkson and Sayers (1999) assert that the forced increase on the fibers stretch will affect the Ca^{2+} channels on the membrane, increasing its flux to the muscle interior. This increment might take the mitochondria to a cell breathing inhibition, causing a break on the ATP regeneration, which is necessary to actively take the Ca^{2+} back to the SR when the muscle relaxes (Cheung et al., 2003). They also state that this Ca^{2+} accumulation might also activate proteases and phospholipases, causing a bigger injury to the sarcolemma due to the production of prostaglandins and other substances resulting in apoptosis (REF mitochondrial pathway of apoptoisis).

2.1.3. Inflammation

According to Hume et al. (2004), high stress forces caused by the eccentric contraction causes a rupture of the protein structure on the muscular fibers, especially of the weakened Z lines. Damages on type II fibers increases the permeability of little blood vessels, producing an inflammatory response which increases the interstitial fluid rich in proteins, that produces the characteristic edema after EIMD and the increased cell number on the injured tissue on the first 4 to 20 hours after EE (Ahmadi et al., 2008). First there is an invasion of the neutrophils followed by the monocytes, on the injury spot (Cheung et al., 2003). The monocytes converted into macrophages which also increase in quantity until a 48 hours peak, post-exercise, producing prostaglandins that, on the other hand, sensitize the sensitive nervous terminations, type III and IV, to mechanical, chemical or thermic stimulations (Fridén, 1984). The accumulation of histamine, potassium and cyanine, due to phagocytosis and cellular necrosis, in addition with the high pressure of the edematous tissue and high temperature, will activate the nociceptors from the muscle and from the myotendinous junction (Fridén, 1984). These events may lead to the pain sensation felt in DOMS, resulting in an increased pain with movement related with the respective increase of the intramuscular pressure that creates a mechanical stimulus on the sensitive receptors of pain (group IV) already synthesized by prostaglandins. Another explanation for the pain in DOMS, might be the inflammation of the perimysium and epimysium (Malm, 2001). According to this author, muscular pain might occur because of the liberation of substances from the muscular cells or endothelial cells, mastocytes or macrophages. Most of these substances, like bradykinin, P substance, PGE2 (a type of prostaglandin), are known for causing pain, as nociceptors are found on the interstitial space on the skeletal muscle (Babenko et al., 1999). Despite this hypothesis, Croisier et al. (1996), didn´t find any significant differences of PGE2 increases after concentric and EE, suggesting that it might not be involved on the pain sensation and, therefore, on DOMS.

According to Clarkson and Sayers (1999), the macrophages, like neutrophils, can also contribute to the tissue injury through the production of free radicals and cytotoxic enzymes.

In the process of repairing the muscle injury, the macrophages have an important role, on the first 12 hours post- exercise, on the removal of cellular waste (Clarkson and Sayers, 1999). The acute phase proteins, on the other hand, usually maintain the cellular homeostasis, restoring injured proteins and/or routes proteins so that the lysosomes proceed to their digestion and posterior degradation (Kilgore et al., 1998).

2.1.4. Oxidative stress (OS)

2.1.4.1. Oxygen (O_2)

According to Powers and Howley (2000), the O_2 debt (the over consumption of oxygen post-exercise - EPOC) is the O_2 consumption over the rest level on the post-exercise period. There are, however, several factors that contribute to the EPOC. First, a part of the consumed O_2 on the beginning of the recovery period is used to resynthesize the creatine phosphate stored on the muscles and to replenish the O_2 “stock” on muscles and blood. The other factors already contribute, however, to the “slow” portion of EPOC such as: the high body temperature, the O_2 necessary to convert the lactic acid into glucose and the high blood levels of adrenalin and noradrenalin (Powers and Howley, 2000).

As previously referred, type II fibers are the most affected ones after this kind of exercise (Fridén, 1984), which makes that, after this injury, there’s a decreasing on the type II fibers recruitment and a bigger solicitation of type I fibers to an activity (Ahmadi et al., 2008). This authors refer that this slow fibers possess a big oxidative capacity and its recruitment to a certain activity might result on a bigger consume of O_2 in relation with fast fibers. They also add that, after EE, the increase of the intramuscular pressure, of the vasodilatation, and the content of the water, on the muscular level, might change the blood flux and the muscular oxygenation. They also refer that, the possible changes on the recruiting level of muscular fibers after muscular injury induction through EE, can also influence the tissue oxygenation.

Ahmadi et al. (2008) verified a decrease on the saturation of O_2 rest on the tissue level 4 days after EE. On the other hand, Laaksonen et al*.* (2006) detected a local blood flux increase from 2 to 4 days after EE and a respective increase on the saturation of tissue rest oxygen. Kano et al. (2005) observed, in rats after EE, that the O_2 supplement doesn't get at the same time when the injured muscle demands it. Ahmadi et al. (2008) suggest that there is an increase of the cardiorespiratory answer so that it compensates the delay of the O_2 supplement. However, they verified that the blood flux and the O_2 consumption on muscular level returns to their normal values on the first 24 hours without having a conclusion related with the change on the saturation of O_2 rest on the tissue level, leaving open its relationship with the DOMS.

Moreover, according to Schneider and Oliveira (2004), periods of intense exercise might increase the oxidative stress due to temporary hypoxia and reoxygenation, which happens on the exercised muscle according to the cycles of contractions and relaxing of the muscles. During the contraction, the vascular compression creates ischemia and, therefore, hypoxia. In relaxation, the reperfusion occurs and, consequently, reoxygenation, normally associated with OS (REF).

2.1.4.2. Reactive Oxygen Species (ROS)

The ROS production, after exercise, was always assumed as harmful to the muscle. Hellsten et al. (1997) report that, after EE, on the next 4 days, the ROS production is the result of a second inflammatory process, with leukocyte invasion containing xanthine oxidase. This enzyme uses oxygen as a receptive electron and generates the oxygen free radicals that might contribute to the aggravation of the muscular injury.

On the other hand, Lowe et al*.* (*cit. in* Close et al. 2004) observed that the produced ROS during EE have an important role on the removal of damaged cells, a necessary action that occurs before the muscular regeneration. However, Close et al. (2004) verified on their study that the production increase of ROS occurs when the pain peak is decreasing and the muscular function is returning to its normal values, which suggests that the ROS are not responsible for the start of the injury but have an important role on its recovery.

2.2. Consequences of DOMS

Eccentric exercises might affect non trained people but also the performance of athletes that compete on higher levels, especially in offseason trainings, when there is a reduction of the maximum power, decrease of the movement amplitude, sensibility increase, muscular pain, edema, muscular hardness and an increase of muscular proteins on the blood (Sayers and Dannecker, 2004).

Eccentric muscle contractions may induce skeletal muscle damage (Friden et al., 1983; Crameri et al., 2007), which manifests itself as a range of signs or symptoms. These symptoms are known to develop in different levels across individuals, including DOMS, swelling, decreased range of motion, prolonged muscle dysfunction and leakage of muscle proteins into blood circulation (Clarkson et al., 1992; Proske and Allen, 2005; Chen et al., 2011).

In fact, some studies reported that the damage profile or the time course of changes in some indirect markers of EIMD vary between muscles after unaccustomed isokinetic eccentric exercise (Jamurtas et al., 2005; Chen et al., 2011). For example, Chen et al. (2011) recently compared the damage profile of four limb muscle groups within the same individuals. They demonstrated that elbow flexors and extensors are equally more susceptible to muscle damage than leg muscles, but the changes in indirect markers of EIMD were smaller for the knee extensors compared with the knee flexors. This suggests that the findings based on an arm model would not be directly extrapolated to the lower limbs.

2.2.1. Maximum Power

Following eccentric activity in persons not accustomed to such exercise a profound reduction in eccentric, concentric and isometric torques [Maximal Voluntary Contraction (MVC) Torque] can be evident immediately following exercise which does not fully recover for many days, or weeks in some cases (Chapman, Newton, Sacco, and Nosaka, 2005; Clarkson et al., 1992; Newham, Jones, and Clarkson, 1987). The largest decrease in MVC torque is usually apparent immediately following the exercise activity with a gradual recovery of force generating ability over subsequent days or weeks (Nosaka, Clarkson, McGuiggin, and Byrne, 1991). Clarkson and Hubal (2002) note that it has still not been positively established exactly how force is lost following eccentric exercise. It seems that the exact mechanism remains to be elucidated. It is, however, thought that the decline in MVC torque following eccentric exercise is initially caused by the high mechanical stress negatively affecting structures involved with excitation-contraction coupling (Ingalls, Warren, Williams, Ward, and Armstrong, 1998b).

There are also other theories, one of which suggests that sarcomeres are non-uniformly stretched during lengthening contractions resulting in damage from 'sarcomere popping' (Morgan, 1990; Morgan and Allen, 1999). Another suggests that the force loss after eccentric exercise may be due to damage at the level of tendon attachments or within the series elastic elements of muscle (Clarkson and Hubal, 2002).

Clarkson and Sayers (1999) refer that, after EE, there are power losses of about 50 to 60%, taking about 10 days to recover the normal values. They add that it's unlikely for the DOMS to result on a decrease of power, because this power is verified right after the exercise before the DOMS is exacerbated, and persists after the DOMS decreases. Ingalls *et al.* (1998) suggest that this power loss is due to problems on the linkage excitation-contraction and decrease on the concentration of contractible proteins. The fact that the sarcomeres have suffered successive stretches might have caused a deformation hard to return to its normal size after contraction (Clarkson and Sayers, 1999).

Croisier et al. (1996) observed that after eccentric effort, the maximum power, measured after 24 to 48 hours was less affected under the effect of ibuprofen. They refer that, this way, the increase on the production of inflammatory mediators, derivatives from the metabolism of the arachidonic acid, through cyclooxygenase, might be associated to DOMS or muscular injury.

2.2.2. Muscle Fatigue

Mammalian skeletal muscles are capable of generating enormous forces when appropriately activated. However, repeated attempts to reproduce equivalent force or power output are invariable met with failure, as characterized by an acute and progressive impairment in performance, which may persist for several days or even weeks. This phenomenon is usually named by neuromuscular fatigue. The etiology of muscle fatigue has interested exercise scientists for more than a century, yet definitive agents remain to be identified. The causes of fatigue during exercise include factors that reside in the brain (central fatigue) and in the muscles themselves (peripheral fatigue) (Ascensão et al., 2003).

Additionally, fatigue manifestations have been associated with muscular power decline generated during and after submaximal and maximum exercises, with the incapacity of maintaining certain exercise intensity on time, with decrease on the rate contraction and with the time increase of muscular relaxation (Allen, Lännergren, Westerblad, 1993; Bangsbo, 1997; Davis, Bailey, 1997; McKenna, 1992; Newsholme, Blomstrand, Ekblom, 1992; Pagala, Ravindran, Amaladevi, Namba, Grob, 1994; Sahlin, 1992a; Sahlin, 1992b). This phenomenon is also related with certain changes of some electromyographic parameters (Guével, Hogrel, Marini, 2000; Masuda, Masuda, Sadoyama, Inaki, Katsuta, 1999; Weir, Mahoney, Haan, Davis, 1999), especially during isometric and dynamic muscular contractions, maximum and submaximal, as well as with the variation of intra and extracellular concentrations of some metabolites and ions (Allen, Lännergren, Westerblad, 1995; Bangsbo, 1997; McKenna, 1992). Fatigue has been, also, suggested as a protection mechanism against possible deleterious effects of the skeletal muscular fiber integrity (Williams, Klug, 1995). In fact, muscular fatigue may result from homeostasis changes on the skeletal muscle itself, in other words, the result of the contractile power decrease independently from the neural impulse speed of conduction, usually named as fatigue with predominantly peripheral origin. It can also be the result of neural input changes that reach the muscle, expressed by a progressive reduction of speed and conduction frequency of voluntary impulse to the motoneurons during exercise, usually named as fatigue with a prominently central origin (Davis, 1995; Davis, Bailey, 1997; Fitts, Metzger, 1988). Additionally, it should be noted that muscular fatigue depends of type, duration and exercise intensity, recruited muscular fibers typology, the subject training level and environmental conditions of exercise realization (Davis, Fitts, 2001; Enoka, Stuart, 1992; Fitts, Metzger, 1988; Roberts, Smith, 1989).Fatigue of central origin translates into a voluntary or involuntary failure on the impulse conduction which promotes a reduction on the number of active motor units and a decrease of the motoneurons firing frequency (Stackhouse, Dean, Lee, Binder-Macload, 2000; Sunnerhagen, Carlsson, Sandberg, Stålberg, Hedberg, Grimby, 2000). The possible role of the central nervous system (CNS) on the origin of fatigue is, usually, studied using techniques designated by interpolated contractions (Allen, Lännergren, Westerblad, 1995; Stackhouse, Dean, Lee, Binder-Macload, 2000). On these studies, the maximum power voluntarily generated by the subject is compared with the power supra maximally produced by exogenous electrical stimulation of the motor nerve or by the muscle itself (Allen, Lännergren, Westerblad, 1993; Davis, Fitts, 2001). Initially, the results from some of those studies seemed to demonstrate that, on trained and motivated subjects, the overprint of a supra maxim electric stimulus didn’t translate, usually, on a power increase in isolated muscles during fatigue (Davis, Bailey, 1997). This premise was used many times to conclude that the decrease of nervous activity on impulse conduction and, therefore, of the nervous system, didn’t represent a factor leading to the installation of muscle fatigue. However, more recent studies prior to the ones mentioned above seem to indicate the existence of a sensorial feedback that inhibits the motoneurons discharge tax during fatigue, justifying the importance of central mechanisms on the maintenance of a certain power level (Davis, Bailey, 1997; Davis, Fitts, 2001; Gandevia, 2001). This inhibition may result from a mechanism of reflex feedback from the mechanoreceptors, namely from muscle spindles and/or Golgi tendon organs, or nervous terminations type III and IV, which seem to be sensitive to the accumulation of some metabolites on muscular level during exercise Davis, Bailey, 1997; Gandevia, 2001).

However, it does not seem to exclude the important contribution of deficit on impulse conduction from superior brain regions as the cause of fatigue. Recent techniques using transcranial magnetic stimulation have, also, provided evidences about the role of superior mechanisms of the SNC on fatigue, particularly on the decrease of cortical activity, on corticospinal conduction of the nervous impulse, as well as on the activation of cerebral areas leading to a bigger dopamine production (Davis, Bailey, 1997; Davis, Fitts, 2001; Gandevia, 2001; Taylor, Allen, Butler, Gandevia, 2000).

Regardless of any terminological conflict with respect to some peripheral fatigue types (Segersted, SjØgaard, 2000), particularly between low frequency fatigue (LFF) and high frequency fatigue (HFF), it's obvious a framework of particularities that differentiates them. Therefore, LFF is characterized: by a sharp decrease of relative power generated by fibers, when stimulated at low frequency (10-30Hz), compared with frequencies of high stimulation (100Hz); by a slow power recovery and persistency of fatigue signs (expressed on the decrease of around 15-20% of the maximum tension generated by the fiber from the first recovery hour) on the absence of significant electrical or metabolic disturbances (Binder-Macleod, Russ, 1999; Chin, Balnave, Allen, 1997; Favero, 1999; Segersted, SjØgaard, 2000). It should be noted, however, that this type of fatigue isn't caused only by the realization of exercises with stimulation low frequencies (Binder-Macleod, Russ, 1999). Effectively, LFF is, fundamentally, characterized by its duration (hours or days), and the designation "long lasting fatigue" is the suggested terminological alternative (Chin, Balnave, Allen, 1997). The recovery from LFF is, probably, related with the protein turnover tax necessary to regeneration and reparation of muscular protein structures injured during and after the exercise. Some authors suggest that the loss of cellular homeostasis to the ion Ca^{2+}, particularly its cytoplasmic increase, seems to be one of the most probable causes of LFF (Binder-Macleod, Russ, 1999; Chin, Allen, 1996; Segersted, SjØgaard, 2000).

On the other hand, HFF is characterized by power decrease during periods of high frequency stimulation (50-100Hz), and that it's reversible when the stimulation frequency decreases; by power decrease, followed by decrease of the amplitude and duration of the action potential and by the decrease of power, accentuated by the increase of Intracellular Na^+ and extracellular K^+ concentrations, lying recovery dependent from the fast replacement of ionic homeostasis (Jones, 1996; Segersted, SjØgaard, 2000). In fact, the increase of K^+ interstitial concentrations, as a result of its movement to outside the cell during the action potential, has been referred by numerous authors as an important factor in fatigue development during intense exercise of short duration (Bangsbo, 1997;

Bangsbo, Madsen, Kiens, Richter,1996; Juel, Bangsbo, Graham, Saltin, 1990; Juel, Pilegaard, Nielsen, Bangsbo, 2000; Segersted, SjØgaard, 2000). This increase may result from the incapacity of maintaining the ionic gradient around the sarcoplasmic membrane of skeletal muscular fibers, by joint or isolated failure of the Na^+/K^+ membrane bombs responsible for reuptake K^+ from the extracellular space to the cell interior. Consequently, there is a progressive decrease of the action potential amplitude, the sarcolemma excitation and T tubules, as well as a reduction of Ca^{2+} liberation to the cytoplasm and the produced power (McKenna, 1992; Segersted, SjØgaard, 2000). One of the hypothetical mechanisms suggested by Bangsbo (Bangsbo, 1997) to explain the relationship between interstitial accumulation of K^+ and the fatigue development is the stimulation of group III and IV sensitive nervous fibers by K^+. Effectively, the stimulation of these fibers seems to promote an inhibition at the cortical level and on spinal

2.2.3. Edema

As previously referred, the edema might be a consequence of the inflammation caused by EE, where the productions from the muscular injury, such as protein fragments, are slowly removed from the extracellular matrix through the lymphatic system, and might attract water, which causes a localized edema (Clarkson and Sayers, 1999). They also refer that the edema starts inside the muscle and spreads itself to the subcutaneous space 5 days after the exercise. Nosaka and Clarkson (1996) observed that the accumulated fluid is moved outside the perimysium 10 days after EE. The edema might be caused by other factors besides inflammation, like the increase of the protein metabolism on muscular cells and the consequent increase of the osmotic pressure due to muscle reoxygenation as previously mentioned (Malm, 2001).

2.2.4. Muscular stiffness

Muscular stiffness increases immediately after the EE and maintains high levels up to 4 days after exercise (Clarkson and Sayers, 1999). Chleboun et al. (1995) refer that the muscular edema and stiffness might be associated. Fridén (1984) refers that this stiffness is due to the myosin head lack of power, on the formation of bridges, to generate contraction and, this happens in order to prevent a future injury.

2.2.5. Sensibility

The increase of sensibility is more focused on the distal muscle part (Cheung et al., 2003). These authors add that the localization of pain in this myotendinous region might exist due to the high concentration of muscular pain receptors, on the conjunctive tissue.

2.2.6. Range of Motion

Range of motion (ROM) of the elbow joint, determined by the difference between the flexed and stretched elbow joint angle, has been shown to decrease immediately following novel eccentric exercise of the elbow flexor muscles, reaching the smallest angle around three days post exercise and slowly recovering over the following days (Nosaka et al., 1991). Relaxed elbow joint angle, which is determined by the angle at the elbow while the arm is hanging freely by the side of the body, is similarly found to be most a pronounced 3 days post exercise, slowly recovering to baseline,10 days following exercise (Clarkson et al., 1992). The aetiology of the decreased ROM following eccentric exercise remains to be fully elucidated, however, previous research suggests that shortened non-contractile components, change in calcium homeostasis due to muscle damage, decreased strength, and/or swelling may be implicated (Chleboun, Howell, Conatser, and Giesey, 1998; Jones, Newham, and Clarkson, 1987). If swelling is involved it is not thought to play a significant role in the decreased ROM evident immediately following the lengthening contractions (Chleboun et al., 1998).

2.2.7. Limb Circumference

Following novel eccentric activity circumference of the exercised limb increases, usually peaking between three to five days post exercise (Clarkson et al., 1992; Howell, Gary, and Robert, 1993). The exact mechanism causing the increased circumference is not clear but has been suggested to be due to either swelling within the affected muscle fibers (Crenshaw, Thornell, and Friden, 1994), swelling of the connective tissue (Clarkson et al., 1992), or increased synthesis of connective tissue rather than fluid accumulation (Smith, 1991).

2.2.8. Intracellular Protein Release

Intracellular proteins such as CK, lactate dehydrogenase (LDH), myoglobin, and myosin heavy chain fragments are detectable in the blood of individuals who have performed novel eccentric exercise (Hirose et al., 2004; Nosaka et al., 1992; Sorichter, Puschendorf, and Mair, 1999). The most commonly used is CK (Ebbeling and Clarkson, 1989), which peaks about three to seven days post exercise and slowly returns to baseline levels thereafter (Newham, Jones, and Edwards, 1986; Nosaka et al., 1992). Each of the three listed proteins show delayed (24 to 48 hour) increases in the blood (Nosaka et al., 1992), suggesting that exit time from the muscle and / or the time taken to drain into the central circulation from the lymphatic system is protracted. The activity of CK in the blood following unaccustomed eccentric activity is variable among subjects (Clarkson and Ebbeling, 1988) and although increased levels of this enzyme can be used as a marker of muscle damage, it is not recommended that it be used as a quantitative measure of the degree of muscle injury incurred (Clarkson et al., 1986).

2.2.9. Neural adaptations

Researchers note that DOMS and the repeated bout effect (RBE) may have a more systemic outcome, known as cross-transfer or cross education, where the strength gains and reduced soreness seen in conjunction with the RBE, carry over to seemingly uninvolved areas of the body. In a review of 13 studies, Munn et al. (2004) reported that an average increase in strength of 35% in the trained limb was accompanied by a significant 7.8% increase in the untrained limb. The results of this meta-analysis were further supported by Starbuck and Eston (2012). Subjects performed bicep exercises of one arm to induce DOMS and the RBE. Researchers discovered the strength increases associated with the RBE did carryover to the contra lateral arm (Starbuck and Eston, 2012). This suggests that DOMS may be centrally mediated and implies some degree of neural adaptation, as there was no direct training stimulus to the untrained muscles. Reductions in the indicators of EIMD, known as the RBE, have been well documented when eccentric exercises are repeated on ipsilateral muscles (Clarkson et al., 1992; Nosaka and Newton, 2002), while the existence of such adaptation on the contralateral limb remained poorly investigated.

Moreover, Willems and Ponte (2012) recently showed different impairments between dominant and non-dominant quadriceps femoris in maximal voluntary isometric force during early recovery after unilateral isometric contractions. The authors suggested that reduced central drive (i.e. central fatigue) that contributed to the reduction in maximal isometric force could be related to leg dominance. It may thus be speculated that dominant and non-dominant knee extensors are not equally resilient to EIMD following eccentric exercise. In addition to observe no significant differences between dominant and non-dominant arms for any EIMD markers, Newton et al. (2012) reported that some criterion measures (maximal voluntary isometric torque, upper arm circumference, plasma CK activity) showed significant smaller changes following the second bout. This latter data confirmed two previous studies (Howatson and Van Someren, 2007; Starbuck and Eston, 2012) demonstrating an initial bout of maximal eccentric exercise in one arm (i.e. elbow flexors of the right arm) provides protection from the symptoms of EIMD during a second eccentric bout in the contralateral arm (i.e. the left arm muscle). Only one investigation has attempted to examine the existence of cross transfer of the RBE in the lower limbs.

Connolly et al. (2002) observed a significant attenuation of pain after the second bout on the contralateral quadriceps when compared with the initial bout performed 2 weeks earlier. However, isometric muscle strength was not different between bouts. The authors suggested that this significant pain reduction was the result of habituation to pain from the initial bout and concluded that a contralateral effect was not evident. In their investigation, subjects performed a stepping protocol that could lead to insufficient damage unable to elicit a marked adaptation. Further investigations are thus required to address the issue of a potential contralateral RBE following maximal exercise on knee extensors.

2.2.10. Psychosocial mediators

Recently, pain research has recognized the interplay of psychosocial factors and physiological factors in the pain experience (Gatchel et al., 2007). It follows that these psychosocial factors may contribute to the perceived severity of DOMS symptoms. Biopsychosocial proponents suggest that the pain experience does not necessarily result from tissue damage; rather each individual’s pain is dependent upon their genetics, history, current mental status, patient expectations, and socio-cultural influences (Gatchel et al., 2007; George et al., 2007). In one study, researchers took 19 males and 23 females with no history of shoulder pain, and naïve to exercise. Subjects were asked to complete surveys which measured fear of pain, pain catastrophizing and anxiety. Pain catastrophizing has been defined as an unrealistic interpretation of bodily sensations, which leads to the preoccupation that one has a serious problem, and is doomed for the worst outcome (Gatchel et al., 2007). The volunteers underwent shoulder external rotation exercises to induce DOMS and were evaluated 24h post exercise. Those that demonstrated a high fear of pain had more pronounced DOMS symptoms (George et al., 2007), that was supported as these authors investigated the role of fear and a specific gene associated with chronic pain. Subjects completed self-report pain questionnaires and were screened for having the COMT genotype (an enzyme linked to pain modulation). DOMS was induced by having participants perform shoulder exercises and were assessed 24, 48, and 72h post exercise. Those demonstrating high pain catastrophizing beliefs and having the gene associated with low COMT enzyme activity (higher pain sensitivity), were more likely to have elevated pain intensity (George et al., 2008). Trost and colleagues demonstrated a connection between fear avoidance beliefs and DOMS symptoms. Trost, (2011) induced DOMS on the trunk extensors of 30 participants. The researchers found that fearful participants had lower strength production and were hypervigilant to pain sensations. It should be noted that the induction of DOMS in these studies served as an experimental model of pain. Inducing DOMS provides more control over the mechanism of injury in comparison to clinical pain. Intent notwithstanding, these studies indicate that psychological factors, including catastrophizing and fear, can influence the perceived severity of DOMS.

3. Factors that influence DOMS

Several factors such as age (Manfredi et al., 1991), gender (Rinard et al., 2000), training status (Dolezal, Potteiger, Jacobsen, and Benedict, 2000), prior exposure to eccentric exercise (Clarkson and Tremblay, 1988), intra-subject design (Clarkson, Byrnes, Gillisson, and Harper, 1987), race and genetics (Clarkson et al., 2005) have been proposed to influence the magnitude of changes in markers of exercise-induced muscle damage and DOMS following eccentric exercise.

3.1. Exercise type and intensity

The type of exercise is a major determinant of the magnitude of changes in markers of muscle damage (criterion measures). Research has shown conclusively that exercise incorporating eccentric contractions (actions) leads to greater changes than those of an isometric or concentric nature (Clarkson et al., 1986; Friden, Sjostrom, and Ekblom, 1983; Lavender and Nosaka, 2006a). It is also known that the type of eccentric exercise can affect the magnitude of change in these measures. Submaximal eccentric exercise has been reported to cause a similar magnitude of initial damage to that of a maximal bout, however, subsequent damage was smaller (Nosaka and Newton, 2002b). Clarkson and Tremblay (1988) also revealed that eccentric exercise that was lower in volume produced only a modest amount of damage when compared to a higher volume bout.
The velocity and range of motion of the eccentric exercise have also been shown to affect the magnitude of subsequent muscle damage. Chapman, Newton, Sacco and Nosaka (2005) reported that in untrained subjects, when time under tension is constant, fast velocity eccentric exercise produces a larger magnitude of muscle damage than slow velocity exercise. Some, but not all, research has shown that a greater magnitude of damage is caused by eccentric exercise which is performed at long compared to short muscle lengths (McHugh and Pasiakos, 2004; Nosaka and Sakamoto, 2001). Nosaka and Sakamoto (2001) noted that the greater changes following eccentric exercise at the longer ranges of motion appeared to be due to a larger magnitude of damage to the brachialis and biceps brachialis. In contrast, however, eccentric exercise of the human rectus femoris at a short muscle length induced greater muscle damage and produced a decline in peak torque greater than the corresponding long length (Paschalis et al., 2005).

3.2. Muscle Group

It appears that responses to eccentric exercise are different between leg and arm muscles as the magnitude of muscle damage seems greater for arm muscles compared with leg muscles. However, little research has been conducted directly comparing the magnitude of muscle damage between different muscle groups employing the same relative intensity of eccentric exercise. A study by Jamurtas et al. (2005) had subjects perform submaximal eccentric exercise of the knee extensors and elbow flexors while relative intensity was controlled. The results suggested that the magnitude of muscle damage was greater and the recovery of muscle function was slower in the elbow flexor muscles. Whether such variability exists between other muscle groups remains to be elucidated.

3.3. Training

The majority of research focusing on EIMD has employed untrained subjects. Findings from these studies have provided important information in furthering our understanding of the effect of eccentric exercise on muscle function and DOMS, however, they do little to inform us how trained muscle responds to such exercise. In a review Falvo and Bloomer (2006) noted that there is little research that has investigated the response of “trained” individuals to EIMD. This is unfortunate as there is a wealth of research describing the neuromuscular and endocrine adaptations gained from exercise training.

When resistance exercise is employed as the training modality, muscles have been shown to improve their ability to produce force in all contraction modes and improvements in strength have been shown as early as during the first training session (Hakkinen, 1989). Early increases in strength are believed to be primarily neural in nature (Gabriel, Kamen, and Frost, 2006; Jones, Rutherford, and Parker, 1989) and may involve increases in maximal firing frequency, down regulation of inhibitory pathways (Aagaard, 2003) and increased motor unit synchronization (Gabriel et al., 2006). With chronic resistance training, peripheral adaptations such as muscular hypertrophy begin to contribute appreciably to the gains in strength (Deschenes and Kraemer, 2002). Increased absolute amounts of connective tissue have been reported in resistance-trained individuals (MacDougall, Sale, Alway, and Sutton, 1984) leading Stone (1992b) to speculate, that strength training may cause adaptations to these structures allowing them to better resist injury. Depending upon the view one takes of such neuromuscular adaptations it could be argued that resistance-trained individuals are more, equally, or less susceptible to EIMD. The increased strength may allow them to produce and absorb more force and hence increase their chance of incurring damage. Alternatively, the improved peripheral adaptations may provide more resilient muscle and tendon structures and render them less susceptible to EIMD, or both increased strength and muscular resilience may exert equal influence causing the resistance-trained and untrained individuals to exhibit similar susceptibility.

In one of the only studies to investigate CK response, soreness and muscle function following a strenuous resistance training regimen, Vincent and Vincent (1997) reported that trained subjects produced a blunted CK response but soreness and loss of muscle function was no different to the untrained group. The paucity of data involving the response of trained individuals to EIMD suggests that further research is warranted. As a resistance-training regimen typically incorporates multiple sets of both concentric and eccentric contractions performed at relatively high intensity, it seems plausible to presume that individuals undertaking this type of training over a period of time may be conferred some degree of protection against EIMD.

3.4. Repeated Bout Effect

Support for the suggestion that resistance-trained individuals may be at least partially protected against EIMD is found in the phenomenon referred to as the “repeated bout effect”. Research has shown that an initial bout of eccentric exercise in untrained individuals can confer protection against a subsequent bout of the same activity (Clarkson et al., 1992; Ebbeling and Clarkson, 1989).The extent of protection varies depending upon the damage marker examined and lasts for at least six months for most damage markers but is lost between nine and twelve months (Nosaka, Sakamoto, Newton, and Sacco, 2001a).Protection has also been shown to occur when the initial eccentric exercise bout was lower in volume producing only small changes in the markers of damage (Clarkson and Tremblay, 1988). Nosaka et al. (2001b) demonstrated that as little as two maximal eccentric contractions performed by untrained individuals can confer protection against a subsequent bout of 24 maximal eccentric contractions performed two weeks later. It has also been shown by Nosaka et al.(2005) that an initial bout of maximal eccentric exercise of the elbow flexors performed at short muscle length (0.87 – 1.74 radians) provided partial protection against the same exercise performed at long muscle length (2.27 – 3.14 radians). In contrast, McHugh and Pasiakos (2004) reported that in the quadriceps an initial eccentric exercise bout performed at short muscle length did not confer protection against strength loss and pain in a subsequent bout at longer length.

Although there have been a large number of studies investigating the repeated bout effect there is little consensus as to the mechanism behind the phenomenon (McHugh, Connolly, Eston, and Gleim, 1999). In a review addressing the phenomenon McHugh et al. (1999) suggests that neural, connective tissue, excitation-contraction coupling, inflammatory response, or cellular adaptations may be responsible for the protective effect.

3.5. Age

The effect of eccentric exercise on markers of muscle damage in humans of differing age is not clear. Some studies have reported that young and old subjects differ little in their susceptibility to EIMD (Clarkson and Dedrick, 1988; Roth et al., 1999), whereas others (Lavender and Nosaka, 2006b; Manfredi et al., 1991; Ploutz-Snyder, Giamis, Formikell, and Rosenbaum, 2001; Roth et al., 2000) note that older individuals incur a greater magnitude of muscle injury. These conflicting findings also extend to when a repeated bout of eccentric exercise is performed. In a study comparing young and older (>60 years) women Clarkson and Dedrick (1988) had both groups perform two bouts of eccentric exercise of the forearm flexors spaced seven days apart. They noted that, with the exception of muscle shortening, the damage process follows a similar course for both age groups and the repair process was equally as effective with both groups showing the same ability to adapt. In contrast, Lavender and Nosaka (2006b) reported that in older men (>65 years) the protective effect conferred by the initial bout was of lower magnitude than that on the younger adults. They suggested that this may have been due to the older men incurring less muscle damage following the first bout of eccentric exercise, however, they could not rule out the possibility that the protective effect in older adults does not last as long as in younger men.

3.6. Gender

Many studies investigating the response to eccentric exercise have employed research designs that include both genders. Due to greater circulating levels of the hormone estrogen in women it has been the common belief that this gender may be protected from EIMD more than men. Whether the markers of EIMD are affected to the same extent in both genders has been a point of interest and has attracted considerable investigation (Dannecker, Koltyn, Riley, and Robinson, 2003; Rinard et al., 2000; Sayers and Clarkson, 2001; Stupka et al., 2000). In a review of the available literature, Clarkson and Hubal (2001), suggested that contrary to the commonly held belief, women are not conferred greater protection and may in fact experience a greater magnitude of damage (based on indirect measures) than men.

3.7. Genetics

To date, there has been little research addressing the question of whether genetic differences affect the responses of markers of muscle damage following maximal eccentric exercise. Two studies employing maximal eccentric exercise of the elbow flexors provide contrasting findings. Gulbin and Gaffney (2002) reported that variability in changes of markers of EIMD cannot be attributed to genetic differences, whereas Clarkson et al. (2005), reveal that phenotypic responses to muscle damaging exercise are influenced by variations in genes coding for specific myofibrillar proteins. The studies differed in their research approaches with Clarkson et al. (2005) studying genotype associations via blood samples, while Gulbin and Gaffney (2002) investigated responses of 16 pairs of identical twins without genetic assessment of blood or muscle samples. Clearly additional research is required to resolve the issue of whether and / or to what extent genetic variation is associated with phenotypic responses to EIMD.

3.8. Racial Background

There is little research investigating the effect of racial background on responses to exercise-induced muscle damage. In a study Clarkson et al. (2005) reported that there were a disproportionate number of asian subjects who were homozygous for the MLCK 49T, a rare allele of the gene coding for the myofibrillar protein myosin light chain kinase (MLCK). These subjects produced significantly elevated CK and myoglobin activity following maximal eccentric exercise compared with the other subjects, suggesting that ethnicity could be a factor. However, the researchers noted that the sample size of asians was too small to draw any firm conclusions. Whether this apparent difference between asian and caucasians extends to other markers of muscle damage remains to be elucidated and warrants further investigation.

4. Models of DOMS and EIMD

There has been a number of different exercise models used to induce EIMD and DOMS in humans. Those producing the greatest magnitude of exercise-induced muscle damage and soreness have incorporated eccentric muscle actions and include models such as:

<u>Bench stepping</u> (Newham, Jones, Tolfree, and Edwards, 1986);

<u>Downhill running</u> (Eston, Finney, Baker, and Baltzopoulos, 1996; Schwane, Johnson, Vandenakker, and Armstrong, 1983);

<u>Downhill backward walking</u> (Nottle and Nosaka, 2005);

<u>Running down stairs</u> (Friden, Sjostrom, and Ekblom, 1981);

Plyometric jumping (Jamurtas et al., 2000; Marginson, Rowlands, Gleeson, and Eston, 2005; Miyama and Nosaka, 2004);
Maximal isokinetic actions of the arms (Chen and Hsieh, 2001; Gleeson, Eston, Marginson, and McHugh, 2003; Philippou, Bogdanis, Nevill, and Maridaki, 2004) and legs (Byrne, Eston, and Edwards, 2001; Paschalis et al., 2005);
Isoinertial exercise (Fielding et al., 2000; Lee et al., 2002; Nosaka and Newton, 2002b),
Eccentric cycling (Walsh, Tonkonogi, Malm, Ekblom, and Sahlin, 2001),
Electrically stimulated forced lengthening exercise (Gleeson et al., 1998; Nosaka, Newton, and Sacco, 2002c)
Drop jumps (Miyama and Nosaka, 2004a; Goodall and Howatson, 2008; Howatson et al. 2012).

It appears that the magnitude of muscle damage varies among the models. In a review, Clarkson and Hubal (2002) reported that, in terms of strength loss and recovery time, the greatest magnitude of change is associated with high-force eccentric exercise. From work cited in the review it can be determined that high-force eccentric exercise often generates up to 35%-40% greater force reductions than eccentrically-biased downhill running (Clarkson and Hubal, 2002).

5. Prevention and treatment strategies for DOMS

There are numerous studies trying to find out ways of preventing DOMS. The lack of preventive measures or even treatment is due to the fact that the mechanisms which surround DOMS aren't completely clarified, existing just hypothesis (Barnett, 2006).
There are, however, proposals to relieve DOMS symptoms, so that they can restore as soon as possible the muscular function and/or reducing the magnitude of the initial injury. These treatment strategies include:
Cryotherapy (O´Connor and Hurley, 2003), produces a decrease in temperature, causes vasoconstriction and therefore a decreasing of the edema and the metabolism that additionally, reduces the inflammatory response, vascular permeability and edema formation;
Flexibility training (O´Connor and Hurley, 2003), after EE might help on the edema dispersion and stress reduction on the motor units of the muscle;
Anti-inflammatory drugs (Lanier, 2004), that inhibit the arachidonic acid metabolism which, on the other hand, prevent the production of prostaglandins and so, the inflammatory response decreases, reducing also the edema and the intramuscular pressure, factors that contribute to the muscular pain;

Ultrasounds (O´Connor and Hurley, 2003), that through heat production promotes an inflammatory response, and acts as a preventive measure and while increasing blood flux;
Electrotherapy (O´Connor and Hurley, 2003), that through analgesic chains tries to diminish muscular pain, accelerating the recovery process and decrease inflammation;
Homeopathy (Cheung et al., 2003), where the most used drug is arnica due to its analgesics, antibiotic and anti-inflammatory properties;
Massage (O´Connor and Hurley, 2003), that increases the blood flux preventing the neutrophils invasion, decreasing the production of prostaglandins, reducing, therefore, a future injury associated with the inflammatory process;
Compression (O´Connor and Hurley, 2003), that, locally, reduces the muscular edema, promoting recovery in power production; Wearing a compression garment on the limb following eccentric exercise has also been shown to reduce some of the markers of muscle damage. A research by Kraemer et al. (2001) showed that compression prevented loss of elbow extension, decreased soreness, reduced swelling, and enhanced recovery of force;
Magnetic therapy (Mikesky and Hayden, 2005), used to reduce pain and accelerate the recovery process through the increase of blood flux on the tissue level;
Acupuncture (O´Connor and Hurley, 2003), because of its efficiency on pain and on neuromuscular function and modulation of the inflammatory response;
Hyperbaric oxygenotherapy (Bennett et al. 2005), where the O_2 increase on the blood helps to restore the Ca_{2+} homeostasis rupture, activating the Ca_{2+} transportation back to the SR and on the mitochondrial regeneration of ATP;
Immobilization has shown reductions in magnitude of some of the muscle damage markers such as CK response (Chen, Nosaka, and Lin, 2005; Sayers, Clarkson, and Lee, 2000b) and swelling (Chen et al., 2005), and an enhanced recovery of muscular strength (Chen et al., 2005; Sayers, Clarkson, and Lee, 2000a; Sayers et al., 2003);
Nutritional supplementation has produced mixed results with differing responses between supplements. Four supplements that have received some attention, these are creatine monohydrate, beta-hydoxy-beta-methylbutyrate (HMB), and vitamins C and E. Rawson et al. (2001) reported that 5 days of creatine supplementation did not reduce indirect markers of muscle damage or expedite recovery following eccentric exercise. Van Someren et al. (2005) reported that combined supplementation with HMB and alpha-ketoisocaproic acid reduced signs and symptoms of EIMD in non-resistance trained males. Another study by Paddon-Jones et al. (2001), however, noted that short term supplementation with HMB had no beneficial effect on a range of symptoms associated with eccentric muscle damage. Similar contradictory results have been reported with respect to supplementation with vitamin E. In reviewing the available literature Goldfarb

(1999) noted that the effects of vitamin E supplementation has produced mixed results and warrants further research reporting that there is a paucity of good research on the effectiveness of this supplement.

Exercise (O´Connor and Hurley, 2003), existing a bigger consensus on this form of treatment, where the exercise is executed before the induction of DOMS, which might help on its reduction through an adaptation by the muscle, or after that induction where there is a temporary reduction of DOMS due to the waste removal increase or the liberation of endorphins during the activity.

There are, however, varied questions that still persist as far as DOMS is concerning, and, therefore, it is necessary more investigation on this area.

6. The Heidelberg Model of Traditional Chinese Medicine

Today there exist modern approaches to Traditional Chinese Medicine (TCM), integrating the fundamental principles of classical TCM theory into the current knowledge of human anatomy and physiology. The Heidelberg Model of TCM is an example. It presents a cybernetic model to systematize the diagnosis and treatment of TCM.

The Heidelberg Model of TCM is based on a system of sensations and discoveries to establish a functional vegetative state or to describe functional abnormalities through its signs and symptoms resulting from disorders of the body tissues (Porkert, 1983; Greten, 2010). This condition can be treated by the use of Acupuncture, Moxa, TuiNa, Pharmacotherapy, Dietetics, Psychotherapy, TaiChi, and Qigong (Greten, 2010).

According to the Chinese medical thinking, the individual is rated holistically, in order to detect phenomenon that are precursors of organic and functional changes that cause the appearance of symptoms and signs. Thus, all information and relevant characteristics of the patient are brought together to form a "pattern of disharmony", the resulting imbalance process, caused by the environment, external source, or by the size of emotional retained efforts, of internal origin which describes the functional state of the patient and consequently provides the framework for the treatment. According to the Chinese medical perspective, the mind and body are not viewed as a mechanism complex, but as a circle of energy and vital substances interacting with each other to form the body.

“Qi”

One of the fundamental concepts of TCM's “Qi”, usually translated as energy, life force or vital energy is the basis of everything, an immaterial form that promotes dynamism, the activity of the living being. According to the Heidelberg model, “Qi” is understood as the capacity for vegetative function of tissues or organs that can cause the sensation of pressure, tear or flow (Greten, 2010).

According to Porkert (1983), “Qi” is defined as the immaterial energy with a qualification and direction.

In Chinese medicine, the “Qi” has two main aspects. On one hand, designates the essence (Jing), which has the function of constructing the body and the mind (“Shen”). On the other hand, indicates the complex functional activities to maintain both. If the "Qi" flourishes, there’s health; if it is weak, there is pathology, whether it is balanced, there is tranquility, If it doesn´t moves in the wrong direction, there is no pathology. Therefore, processing and correcting the direction of movement of "Qi" is the basis for the motion of “Xue” (Blood) transformation of essence (Jing), movement of body fluids, food digestion, nutrient absorption, excretion, wetting the tendons and bones, hydrating the skin and increase resistance to external pathogenic factors (Greten, 2010).

“Shen”

“Shen” is comparable to the ability to carry out certain higher brain functions in Western medicine (Greten, 2010). According to Porkert (1995), “Shen” is the force that originates from the constellation of the orb of the heart and is another expression of extremely specialized "Qi". Greten (2010), defines “Shen” as the functional capacity to put in order mental association and emotions, creating thus the presence of mind. The functional status of “Shen” is assessed by signals such as coherence of speech, the “sparkle” in the eyes and fluid fine motorics.

“Xue”

The “Xue” despite having a different concept of blood in Western medicine, is the functional capacity (energy) linked to body fluids, functions of warming, moisturizing, create "Qi" and nourishing the tissues (Porkert, 2001). It is driven by the "Qi" in the system of channels - conduits. From the standpoint of the Western medical sciences, the clinical effects of “Xue” can be compared to the effects of microcirculation, including functional relationships, blood cells, plasma factors, endothelium and parenchyma (Greten, 2010).

“Xue” has a dual nature: it is part of the Yin and substance, and at the same time is a form of Yang energy. This dual nature of “Xue” becomes obvious in functional relation of “Xue” “Shen” and since the “Xue” (Yin) "checks" / or "controls" the “Shen” (Yang) (Greten, 2010).

Yin and Yang

The concepts of Yin/Yang are probably the most distinctive and important of the whole theory of Chinese medicine, and are used to explain the organizational structure of the human body, their physiological functions, and laws relating to the causes and evolution of diseases. They are not absolute terms but comparative ones. One thing can be rather Yang then Yin or vice versa but not absolutely. Thus, under this view, Yin and Yang are manifestations of a duality, an alternation of two opposite stages in time. Every phenomenon in the universe is changed by a cyclic movement of ups and downs, and the alternation of Yin and Yang is the driving force of this change and development, i.e. each phenomenon may belong to Yin or Yang, but always contains the seed opposite the stage itself. The day turns into night, summer into winter, deterioration in growth and vice versa. Thus, the development of all phenomena in the universe is the result of an interaction of two opposing stages, symbolized by Yin and Yang, and each phenomenon itself contains both aspects in varying degrees of expression. The day belongs to Yang, but after reaching its peak at noon, the Yin within it gradually begins to unfold and manifest (Porkert, 1995).

So in Chinese medicine is pertinent to understand the Yang as an active aspect, an activity / function, while the Yin has a constructive and structural character. All body structures, organs and phenomena contain a predominant character Yin or Yang, fundamental for the balance of the human body. The two forces regulating Yin and Yang must be in a dynamic equilibrium that maintains normal physiological activities of the organic system. If this balance is affected by factors like illness, with predominance or lack of one of the two parties, pathological processes then manifest themselves (Greten, 2010).

The Heidelberg Model of TCM, based on a simple concept of a self regulated cybernetic system confronts the Yin and Yang, explaining the circle of the classical binomial through circular functions in a manner resembling a simple sinus curve (Greten, 2010).

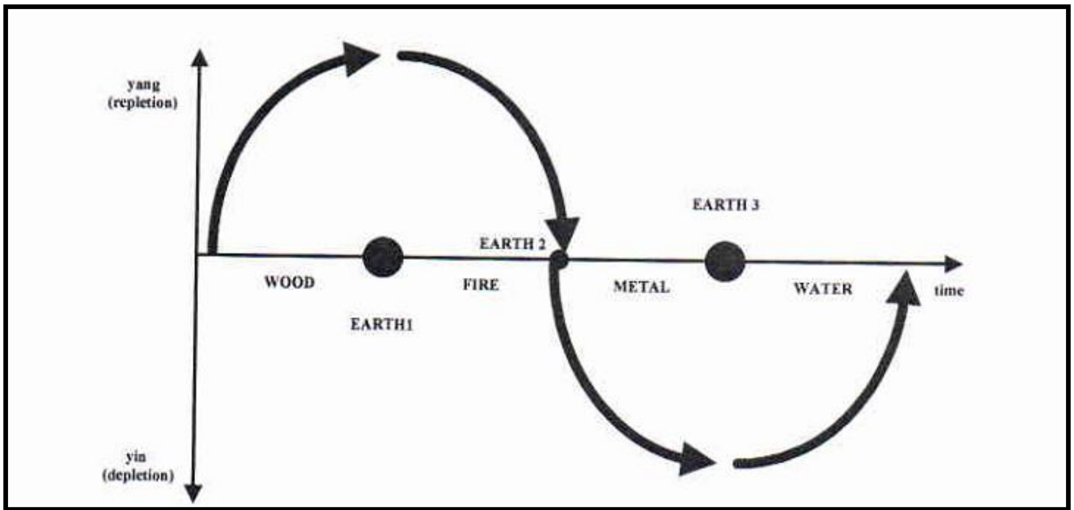


Figure 3 - Phases in a sinus wave (Greten, 2010).

This symbol is a good description of Yin and Yang, the five phases and their linkages: the center (Earth) as a vector that contributes to the equilibrium exercises a down-regulation in the 1st half of the movement and an upward adjustment in second half. Yang or repletion / excess is represented by an increased activity above the center. The Yin or depletion / deficit is reflected by an activity below the target value (Greten, 2010). According to Greten (2010), we talk about Yin or Yang depending on whether it is above or below the "target value" respectively.

Phases and Orbs

In TCM the five evolutionary phases designate vectors that are representative of five qualities of natural phenomenon, five movements, five stages (Wood, Fire, Earth, Metal and Water) and relate to the movement of "Qi", used to classify all phenomena, areas, sounds, smells, tastes and all the familiar things in the universe, there is a link between the five evolutionary phases (vegetative trend) and orbs (organs), the anatomical regions and emotions (Greten, 2010).

According to the scientific approach of the Heidelberg Model for Chinese Medicine, one phase is that part of a circular process, which when applied to humans, shows the trends of the individual functional vegetative state at that particular time. These manifestations are called orb. Each stage corresponds to one vector and a distribution of "Qi" which leads to specific signals that could be relevant to the diagnosis (orbs) (Greten, 2010).

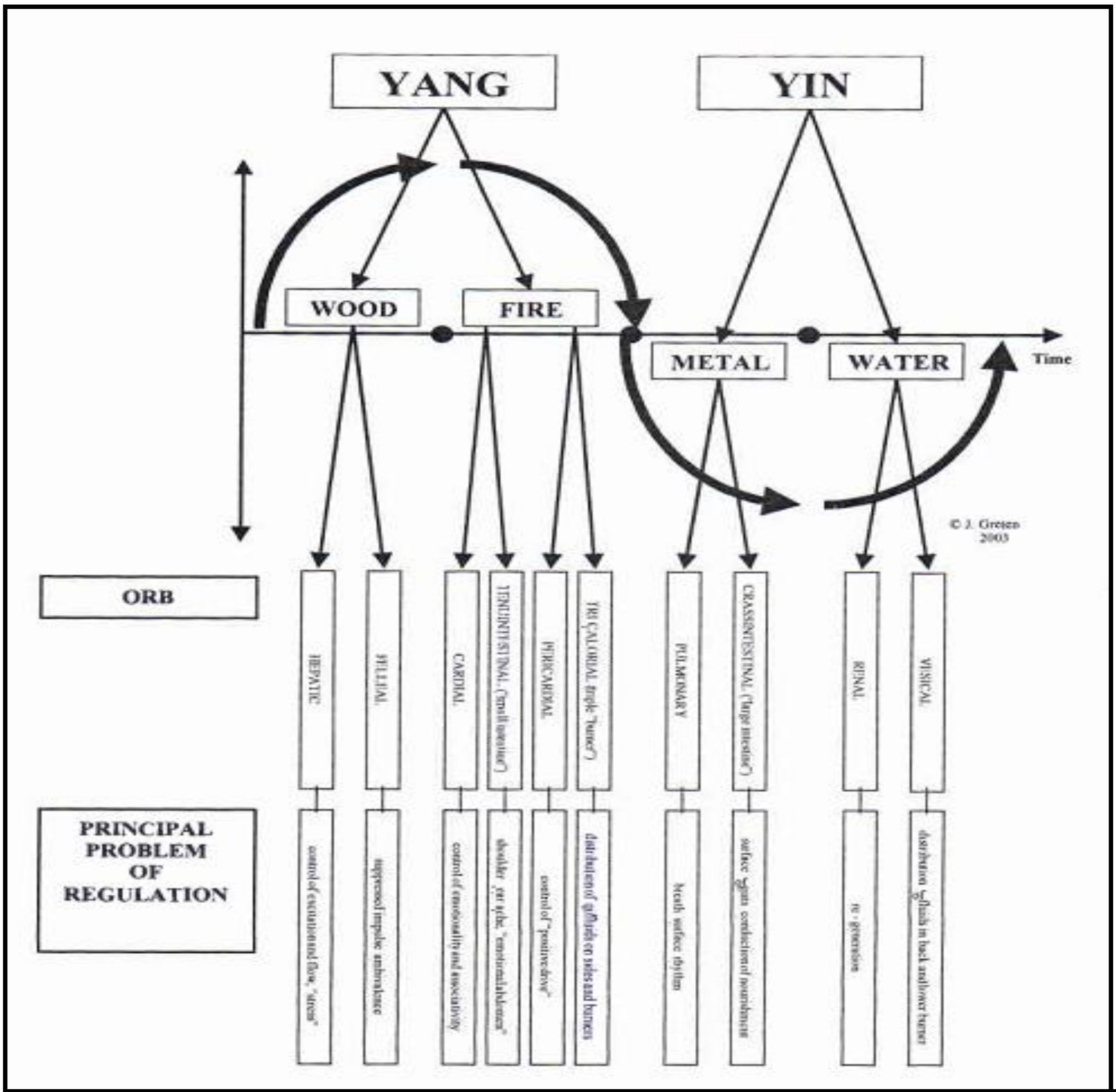


Figure 4 - Diagnostic pathways (Greten, 2010).

The phases consist of a cyclic ordering that can be registered as a sinusoidal wave around a target value (axis). Each phase is represented by two orbs, one with Yin characteristics and the other with Yang characteristics, with the exception of the phase Fire having four orbs. This sinus wave analyzes the problems of transition from one phase to another. This circular function is called cybernetics and explains how the Yin and Yang and the circular functions are important to medicine and represents a model of regulation (Greten, 2010).

It is a very useful tool in the analysis of problems of transition from one phase to another. The model of the six stages, aka *Algor* Laedens Theory uses a sinusoidal curve in order to characterize the action of the orthopathy (the "straight path" or the healing power of the body). In Western terms this is the action of the immune system. Thus, in accordance with the laws that describe regulatory processes (cybernetics), the episodes of periodic fluctuations that exist around a target value, activating and deactivating the systems and mechanisms of transition are responsible for the bodily changes that will manifest in different functional vegetative states of body and that come with, and are shown through the sinusoidal curve. The more we move away from the target value regarded as normal, the more mechanisms of self regulation are active. This is symbolized by the vectors leading the effective value to normal. If we project these ortopathic force vectors we get a reverse sinusoidal curve (Greten, 2010).

According to the western medical sense, the figure 5 shown may be representative of the global vegetative activity, including central nervous system via the transmitter and vegetative systems involved (Greten, 2010).

The phases Yang (Wood and Fire) are mainly regulated by the sympathetic nervous system functions, whereas the phases Yin (Metal and Water) dominate the activity of the parasympathetic nervous system (Greten, 2010).

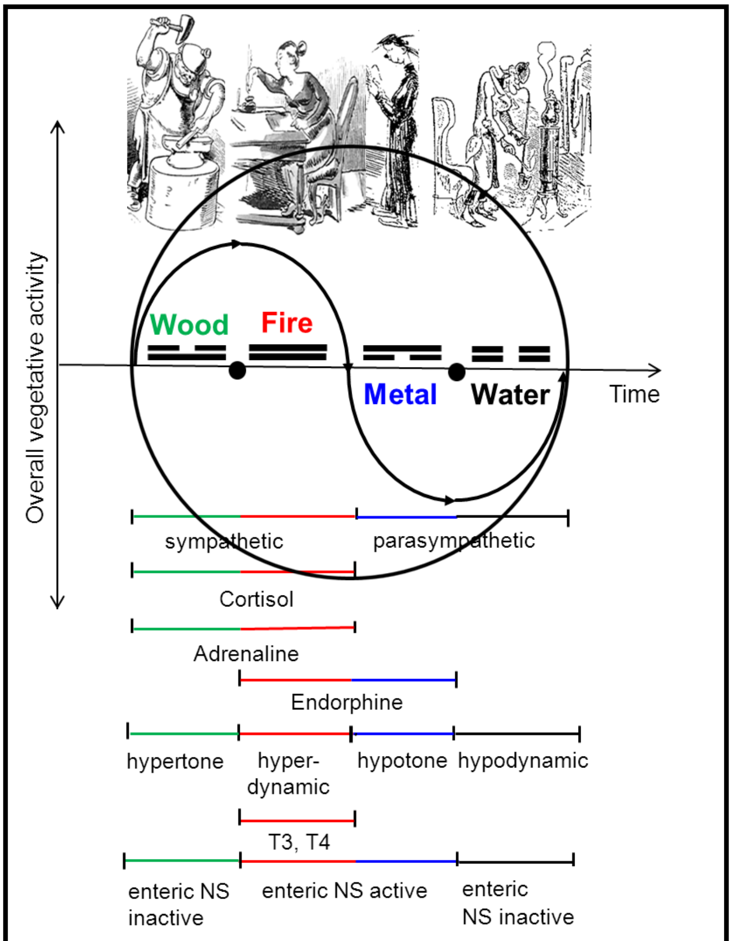


Figure 5 – Vegetative system and phases (Greten, 2010).

Conduits

Conduits are a connection of a group of points with effects on the clinical signs of an orb, believed to serve as a conduit for the flow of “Qi” and “Xue” (Greten, 2010).

There are 12 cardinal conduits extending which extend duplicated and symmetrically between the left and right side of the body connected to a corresponding orb. Every Yin conduit is connected to a Yin orb, as each Yang conduit is connected to a Yang orb. However, each Yin conduit finds its complementary Yang pair at the level of the tip of the fingers or toes. The polarity Yin \ Yang and *intima* \ *extima* is evidenced in the layout of the complex system of conduits. The Yin conduits are presented by the anterior region or

abdominal, and the inner side of the limbs. Regarding Yang conduits, these are presented in posterior region, head and back, and on the outer side of the limbs (Greten, 2010).
There are other two conduits, *sinartéria regens* and *respondens*, as well as others collaterals. Although, in western medicine, there are no simple correlations and scientific support for the existence of conduits and collaterals, it´s unavoidable to think of them as combinations of the vascular, nervous and neuroendocrine systems (Greten, 2010).

The stomachal conduit

The stomachal conduit (Yang), along with the Lienal conduit (Yin), represents the "Earth" phase. In general, this phase is characterized by harmonizing and regulates the functions of all other orbs (Greten, 2010).
The stomachal conduit represents the connection of 45 individual acupuncture points arranged along the body surface. The course of the conduit starts in the face (forms a "U"). It runs down the thoracic wall at line 4 cun lateral to the nipples and then the abdomen 2 cun lateral of the mid-line. As an extimal conduit it finally goes over to the outer side of the leg. It ends at the outer side of the second toe (Greten, 2010).
The route of the conduit is shown in figure 6.
This conduit describes it´s flow in a downward direction which in terms of regulation, down-regulation corresponds to the stomachal orb (Greten, 2010).

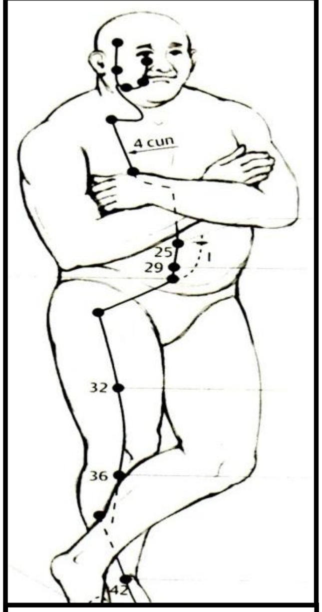


Figure 6 – The stomachal conduit (Greten, 2010).

The hepatic conduit

The hepatic conduit (Yin), along with the Felleal conduit (Yang), represents the "Wood" phase. In general, this phase is characterized by creating potential. In a physical way this means that the potential is an amount of energy, and energy is the capacity of exerting work (Greten, 2010).
The hepatic conduit represents the connection of 14 individual acupuncture points arranged along the body surface. The course of the conduit starts at the inner side for the big toe. As an *intimal* conduit, it runs up on the inner side of the leg. It ends in point H14 in the 6th intercostals space of the medioclavicular line (Greten, 2010).
The route of the conduit is shown in figure 7.

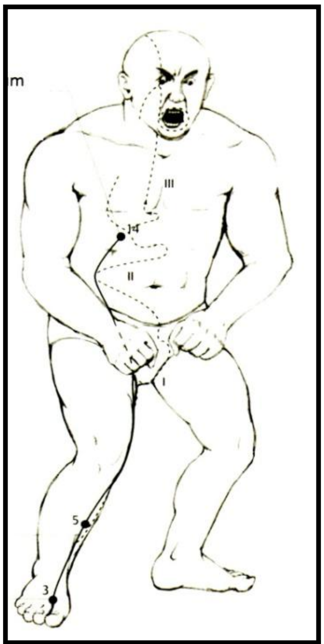


Figure 7 – The hepatic conduit (Greten, 2010).

This conduit describes it´s flow in an upward direction which corresponds to the vector of Wood (Greten, 2010).

Traditional Chinese unit of length (Cun)

Cun is a traditional measure which is the width of a person's thumb at the knuckle, whereas the width of the two forefingers denotes 1.5 cun and the width of four fingers side-by-side is three cuns (Focks, März, and Hosbach, 2008). This is a very useful measure to find acupuncture points on the human body as we used in this study. Cun measure is shown in figure 8.

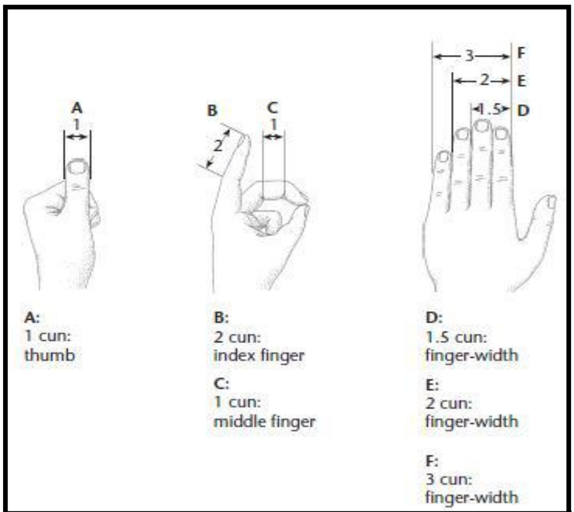


Figure 8 – Cun measure (Focks, März, and Hosbach, 2008).

6.1. TCM diagnostics according to the Heidelberg model

Diagnosis in TCM should become more standardized, rational and communicable. According to the Heidelberg Model, in order to establish the diagnosis, we must define the signs and symptoms corresponding to certain principles:

Constitution - gives us the functional properties of the individual and his inner nature, primarily based on their phenotype. The posture, tone of voice, facial expression and body are some aspects that characterize the person and allow you to define its constitution. Chinese medicine believes that the physical structure modifies the performance of the man, his feelings, and functions indicate the likelihood of showing certain symptoms (Greten, 2010). Thus, constitutional signals considered "normal" in an individual, may be a manifestation of another's disease, whose constitution is different. The corresponding phases express constitutional types and represent the person's tendency to express a predominant pattern.

Agent - is seen as a power (vector) function, which causes changes in the functional properties of the subject, producing and inducing groups of clinical and diagnostically relevant signs (orbs). Agents can be divided according to so called "climatic excesses" or in to emotions as follows (Greten, 2010):

– External agents: *Algor* (cold) *Humor* (moisture), *Ventus* (wind), *Ardor* (flushing), *Aestus* (summer heat), *Ariditas* (dryness).

– Internal agents: *Voluptas* (Joy), *Ira* (Anger), *Maeror* (Sadness), *Timor* (Fear) *Pavor* (Shock).

– Neutral agents: overwork and stress, bad eating habits, smoking, alcohol, drugs, infection, excessive sexual activity, accidents and injuries.

Orb - refers to the clinical manifestations of one stage that are a group of signals relevant for diagnosis indicating the functional state of a body island and of the corresponding conduit (Greten, 2010).

Guiding Criteria – they can be understood as the interpretation of the regulation of the body based upon the physiology of the four regulatory models which each of the components will allow to perform a functional diagnosis (Porkert, 1985). Current understanding of these features clearly shows that these criteria are an extension of vegetative regulatory system, including processes such as microcirculation (*algor / calor*), defense mechanisms and the relationship between the cellular (Yin) and the regulatory processes (Yang). They are:

– Depletion/Repletion, evaluates the clinical signs that in TCM is believe to be originated primarily from the "Qi" and Orbs. In Western terms: a poor population of cells can be stimulated excessively causing vegetative clinical signs as they were appointed under repletion. Therefore, a stage of near collapse with functional signs may appear similar to depletion (Greten, 2010).

– *Calor/Algor*, evaluates the signs that Chinese medicine is thought to originate from the effects of "Xue" which is the second functional power ("energy") of Chinese medicine. In Western terms, these signs are due to overactivation mechanisms that involves: the microcirculation and local interdependent mechanisms of plasma, blood cells, endothelium and functional tissue of the organ; this is an activation of body fluids, at least in some part of the body; and can evoke vegetative and systemic responses in the context of fluid distribution, supply and circulation of fluids (i.e. changes in thirst, urination, blood supply and heart rate). In summary, clinical signs of this type may be referred to humorovegetative with respect to the origin. Signs of overactivation of “Xue” (effects on the microcirculation) are generally described as *calor*, lack of signs of functional microcirculation are called *algor* (Greten, 2010).

– Extima/Intima evaluates the signs that in Chinese Medicine are believed to originate from the effects of a pathogenic factor (agent) that invades the body from the outside. The most common underlying pathophysiological model is the model of six stages (Shang Han Lun). This is the process of the agent *algor* damaging the body. It is therefore called *algor* laedens theory (ALT) (Greten, 2010).

– Yin/Yang, evaluates signs which, according to Chinese Medicine, distinguish between primary deregulation (Yang) or deregulation due to structural deficiency (Yin). If a functional tissue is deficient, it will be excessively up-regulated to achieve proper function. As this over activation cannot be kept for a determined amount of time functional deficiency appears (Greten, 2010).

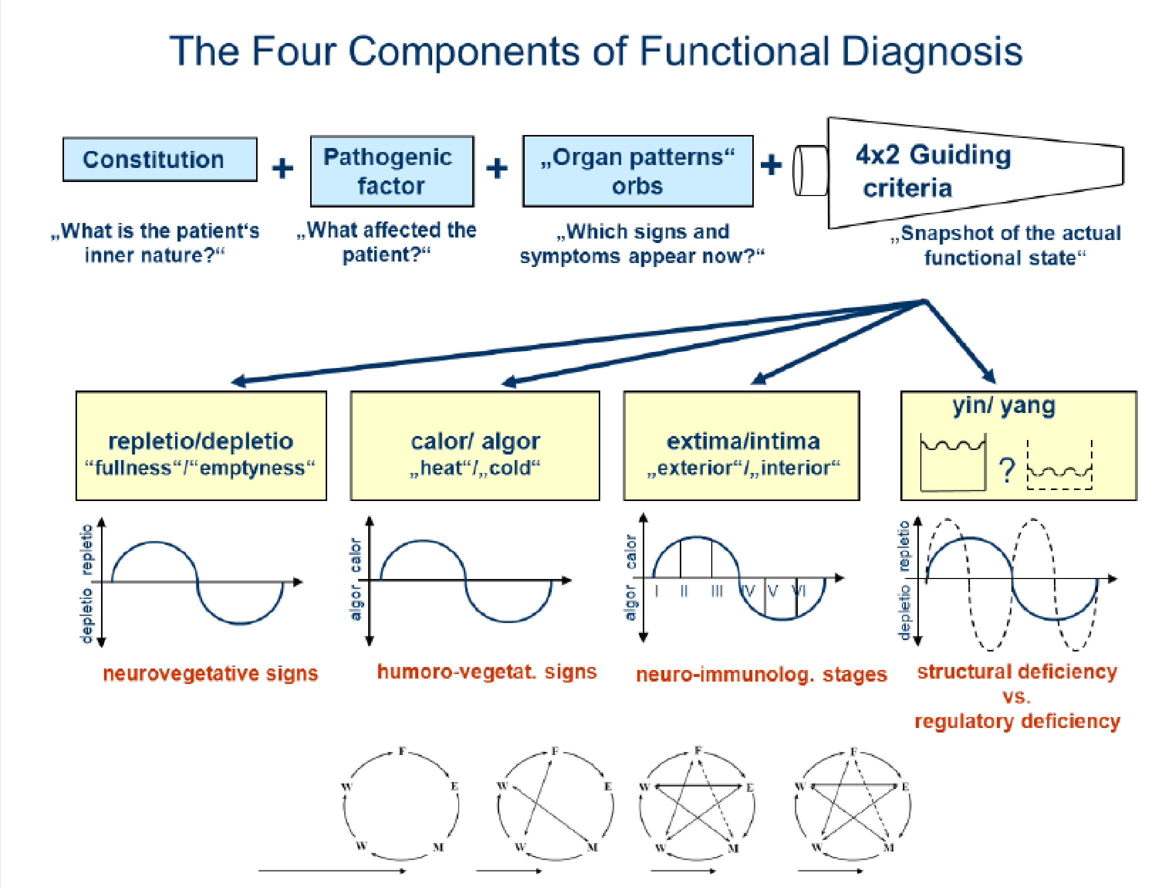


Figure 9 – The four components of the functional diagnosis in TCM (Greten, 2010)

The differential diagnosis in TCM results from joining all data relevant and pertinent, schematically represented and collected by the following assessment tools (Greten, 2010):

Observation - body shape, movements and actions; different parts of the body - (skin, face, lips, tongue and mucous membranes), sound and tone of the voice, cough, and breath odor.

Interrogation - addressing history, possible disturbances accumulated in the past, information on lifestyle, diet and appetite, elimination, respiration, menstruation, temperature sensation, local pain and modality of pain.

Palpation - skin, limbs, hands, chest, abdomen, acupuncture points, radial pulse (constitutes a fundamental method to validate and / or verify some of information collected in the diagnostic and thereby assess the state of internal systems, *“Qi”, “Xue”* and *Yin*).

6.2. DOMS according Heidelberg model of TCM

While western medicine attributes DOMS to local inflammation due to either mechanical damage or swelling leading to ischemia and muscle spasms, TCM views DOMS as localized “Qi” and “Xue” stasis that manifests as pain and soreness of the joints, muscles or tendons. Collectively, this is known as muscle Bi-syndrome (Xinnong, 1987).
The “Qi” and “Xue” become stagnant due to excessive loads from eccentric exercise. This affects the felleal function to transform and transport, and the hepatic function to spread *“*Qi” in all directions. The severity is dependent upon the level of the athlete, along with any underlying conditions that are then exacerbated with this type of exercise. The idea is to prevent DOMS from occurring, which means one must anticipate and understand not only Oriental medicine, but also the concept of eccentric movements.

Acute injuries involve *“Qi”* and “Xue” and include other pre-existing conditions that involve body fluids, conduits and *orbs*. The most common is “Xue” and *“Qi”* stasis that represents an excess condition. While chronic conditions have pre-existing deficiency associated with orbs*, “Qi”*, “Xue” and/or body fluids affect the conduits. In both instances, the *“Qi”* and “Xue” flow become interrupted and can cause stagnation to occur, meaning that *“Qi”* and “Xue” diminish and may become completely obstructed. Conversely, if there is interior deficiency, this will not only support the other *orbs* and their associated pattern functions, but also the conduits (Chuang, 2000).

Pain is a good indicator for a number of reasons. The location identifies the conduits that are involved. The quality of pain provides information as to the severity of the patterned involvement of *orbs*, “Qi”, “Xue” and body fluids. The pain also indicates the degree of excess and/or deficiency with the associated condition. This information will help differentiate pre-existing conditions associated with pain rather than just the symptoms (physiological manifestations) (Chuang, 2000).

TCM attributes the muscle damage on hepatic “Qi” stasis leading to hepatic Yin or hepatic “Xue” deficiency. Once the tear or sprain occurs, TCM views this as a type of Bi-syndrome otherwise known as painful obstruction (Chuang, 2000). Bi-syndrome exists in many forms depending on what symptoms are present. It is usually caused by external factors including *ventus, algor, calor,* or *humor*. It can also be caused by traumatic injury. Within Western medicine, most sports injuries are categorized into three phases defined as acute, sub-acute, and chronic (Chuang, 2000). The acute phase refers to the first 72 hours after the onset of the injury and is usually characterized by swelling, discoloration, sever localized pain, and decreased range of motion. The sub-acute stage ranges from 72 hours to 90 days after the injury and is the stage most receptive to treatment by acupuncture or most vulnerable to improper care. The chronic phase is defined the injury state after 90 days. TCM acknowledges these phases by differentiating them into different types of bi-syndrome. For example, during the acute or even the sub-acute stage, the injury could be classified as muscle bi-syndrome but later transform into painful, fixed, or *calor* bi-syndrome depending it's specific symptoms (Chuang, 2000).

In all circumstances, however, moving the "Qi" and "Xue" stasis is of primary importance. Additional treatment designed to clear calor, suplete Yin, or suplete Yang may be necessary depending the symptoms that manifest. The common obstacles that plague competitors and can adversely affect athletic performance include anxiety, fatigue, delayed-onset-muscle-soreness, and muscle sprains. Theoretically, TCM-based acupuncture can offer several solutions to these problems.

TCM focuses on simultaneously treating excess conditions, such as moving the "Qi" and "Xue" to prevent stasis from occurring, as well as supporting individualized deficient conditions that predispose an individual to other pre-existing conditions within the *orbs*, such as "Qi" deficiency and stasis, "Xue" deficiency and stasis, pituita accumulation, Yin and/or Yang deficiency - all of which give rise to *ventus, algor, humor* bi-syndrome invasion, exacerbating the condition and invasion of the collaterals. This is all dependent upon the individualized diagnostic methodology, with a number of possible treatment combinations. In differentiating *"Qi"* vs. "Xue" stasis, an easy rule applies: Pain followed by swelling *"Qi"* stasis is predominant; swelling followed by pain "Xue" stasis is more predominant. Usually, they occur together.

The implementation of treatment protocols tends to be very limited in application because this is a sign and symptom-based understanding and does not address pre-existing conditions, as in the TCM preventative model. However, current research in the biological sciences accepts this physiological explanation, at this point, validating the treatment of pain for acupuncture. Having said this, the importance of understanding both perspectives provides a great deal of insight, enabling the differentiation between the two.

7. "Leopard Spot" technique

The leopard spot technique is one of the five puncture techniques described on the classic TCM literature. Also known as "sparrow-pecking technique", it basically consists in fast skin penetrations on a certain acupuncture point (Hauer, et al., 2011; Nabeta, and Kawakita, 2002).

Figure 10 – “Leopard Spot” technique in a participant.

This technique is a method of therapy that is difficult to explain in modern terms. Aside from the traditional theoretical basis for these treatments in letting out *calor* and excess factors, a key issue is whether it actually produces the claimed effects but that it would be relevant to DOMS. Many Western acupuncturists have stated informally that they get dramatic results from this treatment method, but, unfortunately, there is no evidence presented to support such contentions. Despite the frequent mention of treating peripheral points by this technique in both ancient and modern Chinese medical texts, there is little reference to it in Chinese medical journal reports. Very few articles focus specifically on use of this technique. Further, descriptions of therapies for the disorders that peripheral acupuncture is supposed to successfully treat rarely include that method. Instead, standard acupuncture techniques without leopard spot technique, as well as herbal therapies, are described (Wen, 1985; Unschuld, 1985).

The existing studies show the technique effectiveness on the decrease of heart rate (Imai and Kitakoji, 2003) instantaneous decrease of lumbar pain after manipulation of the most painful point (“*Ashi*” point) (Inoue, et al., 2006), decrease of rigidity and also cervical and shoulder pain on short term (Nabeta and Kawakita, 2002) and increase of the blood flux on muscular level with the purpose of decreasing the generated pain by metabolic final products (Shinbara, et al., 2008), one of the possible causes of DOMS and on the presence of *algor* patterns, decreasing of the capillary perfusion and inflammation, another of DOMS etiological factors (Doenitz et al., 2012).

Letting out blood is among the oldest of acupuncture techniques. Indeed, it has been speculated that acupuncture started as a method of pricking boils, then expanded to letting out "bad blood" that was generated by injuries or fevers, and finally allowing invisible evil spirits and perverse atmospheric “Qi” (most notably "*ventus*") escape from the body (Liedberg, 1983). Only later, perhaps as the needles became more refined and as scholars developed of a more subtle theoretical framework, were thin filiform needles used as the primary acupuncture tools for the purpose of adjusting the flow of “Qi” and blood, without necessarily releasing something from the body (Wen, 1985).

For excess type syndromes, bleeding is recommended because it can drain the excess, alleviate congestion and stasis, and remove the pathogens. The function of this therapy is "to drain *calor* or “quicken” the “Xue” and “Qi” and relieve local congestion" (Wiseman and Ellis, 1985).

One of the claims commonly made by Western acupuncturists is that, acupuncture by the leopard spot technique at the jing-well points or at the ear can rapidly decrease blood pressure (Hou jinglun, 1995) and could, at least in theory, alleviate some of the symptoms attributed to the increase in hydrostatic pressure seen in DOMS.

While standard acupuncture therapy is depicted as being effective, in part, by releasing various transmitter substances (i.e., endorphins), by stimulating local blood flow (i.e., by dilating vessels), and by producing changes in the brain that may have both systemic and highly specific effects, letting out a small amount of blood (usually just a few drops) remains without a suitable explanation for the potent effects claimed. The technique used to let out the blood is one of quick and light pricking to pierce the skin and vein. The Leopard Spot technique has four major therapeutic aims that are useful in the clinical arena (Skya Abbate, 2003):

1. It can invigorate the smooth flow of “Qi” and “Xue”, thereby picking up and facilitating its flow when the “Qi” and “Xue” need invigoration. An example of this scenario occurs when a patient presents with a wiry pulse and mild feelings of stagnation that indicate “Qi” stagnation. Improving circulation and preventing “Xue” from remaining stagnated;

2. It disperses “Qi” and “Xue” stasis, as in cases of backache or spider veins;

3. It can drain excess, *calor* and *ardor*. Such excess includes pathogenic factors as in an invasion of *Calor-Venti* in the Pulmonary conduit that produces a fever and extremely sore throat;

4. Finally, bleeding can bring down Yang rising, as in the varieties of high blood pressure due to Hepatic Yang rising.

8. Neurophysiological basis of acupuncture

The physiological response of Acupuncture is defined as a stimulation technique of the various mechanisms of self-regulation of our body through the nervous, endocrine and immune systems (Ferreira, 2010).

This regulation of the nervous system and its effectors is achieved by action at 4 levels: local, segmental or spinal, extra-segmental, and supra-segmental or supra spinal (Ferreira, 2010).

Local: acupuncture stimulates peripheral neurological sensory receptors, in particular the free nerve endings, consisting predominantly of the delta fibers, skin, and muscle fiber type II and III which are interconnected forming a net charge of propagation of the nervous stimulus to blood vessels and local immune cells (Ferreira, 2010). These peripheral receptors propagate the stimulus to local network of neurons and produce what is called "axonal reflex." According to Ferreira (2010), the reflection that occurs without the need for a center cord integration, will induce an increase in local blood supply due to release of various vasoactive substances such as substance P, bradykinin, related polypeptide gene calcitonin, VIP (vasoactive intestinal peptide), Histamine, Serotonin, nerve growth factor, vascular growth factor, etc.

In addition to the local effects as described, there is still the release of biochemical analgesic substances as the β endorphin in large amounts, which potentiate the analgesia locally by acting on the peripheral sensory receptors and blocking nociception (Ferreira, 2010). These substances are released by local inflammatory cells (granulocytes), demonstrating a sort of activation of the immune system by acupuncture.

Segmental or spinal: the gate theory of Melzack and Wall (1965) is fundamental to understanding the so called segmental effect of acupuncture. According to the authors of this theory, a myelinated nerve fiber and high-speed driving (e.g., aδ or aβ) if stimulated in a damaged area, carries its information to the CNS faster than a myelinated fiber with low speed that is stimulated by local pain. On reaching the posterior horn of the spinal cord, these myelinated fibers cause a blockage of nerve impulse transmission originating from the C fibers (slower) (Melzack and Wall, 1065) by enkephalins and release of GABA inhibitory neurotransmitters, released by interneurons at the level of the posterior horns of the spinal cord. The various tissues of our body, even though sometimes very far apart, can have the same innervation as during embryonic development originated in the same segment, allowing us to understand that, to give effect to the level of a particular nerve root, we can put the needles in structures with the same innervation of the affected site, exerting an effect on posterior horns of the spinal cord at the level of the spinal segment stimulated (Ferreira, 2010).

Extra-segmental: this mechanism of analgesia is nonspecific or generalized, depending on the intensity of the stimulus and not its location. It acts by controlling the periaqueductal gray matter in the brain stem, spreading through the descendant inhibitory beams to the posterior horn of the spinal cord, depressing the activity of nerve cells located here.

Supra-segmental: this mechanism of action is located at the level of the cerebral cortex and spreads to the spinal by descending inhibitory beams. After the thalamus and the reticular system process the information received by the impulse of the puncture, it is driven to various areas of the cerebral cortex, including the centers of information processing as a primary sensory cortex or somatosensory, the cerebellum, the limbic system, the prefrontal cortex, among others, each of which, in turn, will respond to these stimuli in its own way (Ferreira, 2010). The use of electrostimulation allows potentiate the effect of supra-segmental acupuncture.

9. The impact of the Heidelberg Model of TCM on current acupuncture research

The Heidelberg Model of TCM revealed that the TCM diagnosis can be regarded as the current vegetative state of the body, which can be defined by key symptoms (diagnostic features). According to the Heidelberg Model, acupoints elicit vegetative reflexes that have to match the current vegetative state of the subject treated in order to be clinically effective (Greten, 2010). In a clinical scenario one single western diagnosis may therefore represent a whole diversity of TCM diagnosis. For this reason it is difficult to define a homogenous study population for an acupuncture trial in which all patients show similar vegetative states at baseline.

In current clinical acupuncture research inclusion and exclusion criteria are conventionally based on the Western diagnosis. As a consequence there is a great risk that the investigated acupuncture intervention might be suitable for some patients while it does not match the vegetative status of others. This might explain why many randomized clinical trials on acupuncture effect have not shown statistically significant superiority of the investigated acupuncture treatment to control treatment groups (Hopwood, Loveley, Mokone, 2001). Hence, there is a clear demand for measurable parameters that help to parameterize different aspects of the current vegetative state of a patient in order to enable a more accurate definition of study populations in future acupuncture trials.

Chapter 2 - Methods

Methods

1. Type of Study

The study was designed as a prospective randomized controlled trial, using a clinical quantitative research model.

2. Organizational structure

This study was performed as a part of a dissertation of the master's program of the Abel Salazar Institute for Biomedical Sciences, in Traditional Chinese Medicine. This research project was conducted in the Hospital-School of Fernando Pessoa University with the technical support of Fernando Pessoa University which has provided the equipment and consumables items used for this study with no additional external funding.

3. Study objectives:

3.1. General objective: The purpose of this study was to evaluate the effects of acupuncture on DOMS.

3.2. Specific objectives:

Verify the effects of the leopard spot technique on acupuncture points (verum acupuncture) on DOMS symptoms

- muscle soreness;
- pressure pain threshold;

Verify the effects of the leopard spot technique on acupuncture points (verum acupuncture) on DOMS neuromuscular function:

- range of motion;
- vertical jump;
- isokinetic (average peak torque; peak torque/body weight)

Verify the effects of the leopard spot technique on acupuncture points (verum acupuncture) versus a nonspecific acupuncture points out of the known conduit system (sham acupuncture) on DOMS symptoms and neuromuscular function.

4. Study hypothesis

H1: Muscle soreness is decreased in the verum acupuncture (VA) group when compared with control group (CG) group.

H2: Muscle soreness is decreased in the VA group when compared with sham acupuncture (SA) group.

H3: Pressure pain threshold is increased in the VA group when compared with CG group.

H4: Pressure pain threshold is increased in the VA group when compared with SA group.

H5: Range of motion is increased in the VA group when compared with CG group.

H6: Range of motion is increased in the VA group when compared with SA group.

H7: Vertical jump is increased in the VA group when compared with CG group.

H8: Vertical jump is increased in the VA group when compared with SA group.

H9: Average peak torque is increased in the VA group when compared with CG group.

H10: Average peak torque is increased in the VA group when compared with SA group.

H11: Peak torque/body weight is increased in the VA group when compared with CG group.

H12: Peak torque/body weight is increased in the VA group when compared with SA group.

5. Ethical procedures

All research was undertaken at Hospital-School of Fernando Pessoa University, located in Gondomar, Porto, Portugal, between June and July 2014 and was previously approved by the Ethical Committee of Fernando Pessoa University (**Annex A**). All participants were previously informed of the study objective, guaranteed anonymity and sign an informed consent **(Annex B)** form in accordance with the Helsinki Statement being informed that they could quit at any moment without consequences.

6. Conflicts of interest

None of the elements of the research team are involved in activities that can represent conflicts of interest.

7. Study design

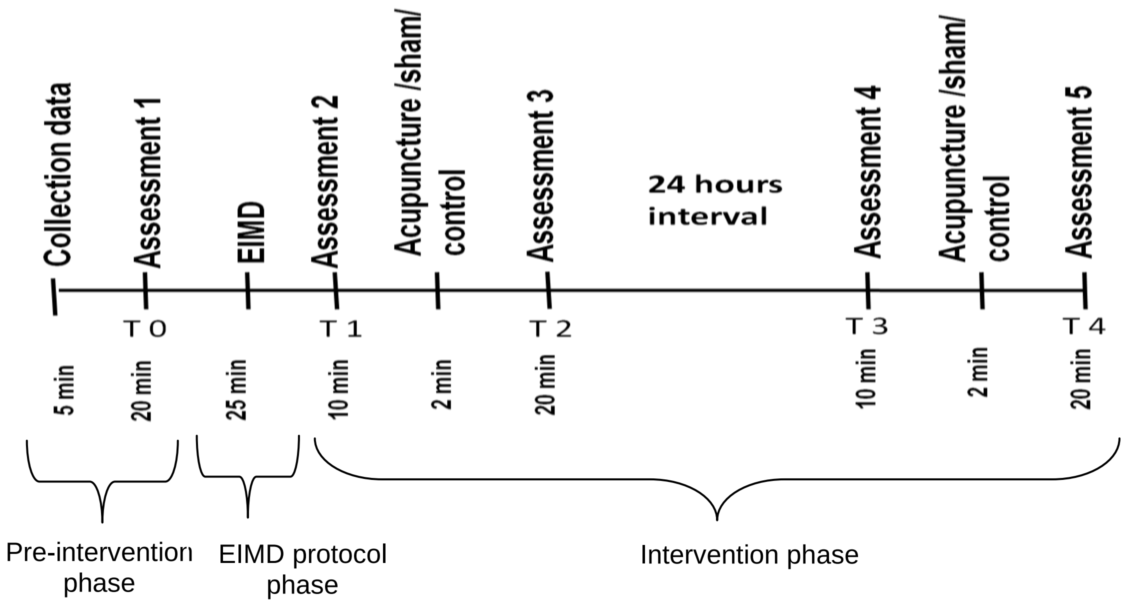
7.1 Pilot Study

A pilot study was carried out before the beginning of the data collection, using four individuals with the same characteristics of the sample but not belonging to it. It was conducted in order to verify all the procedures and calculate the time of the collection to facilitate the programming of the study.

7.2 Experimental Study

The study was divided in 3 phases: Pre-intervention phase, Exercise induced muscle damage (EIMD) protocol phase and an Intervention phase. Figure 11 shows the Experiment flow-chart of this 3 phases.

Criterion measure	Time evaluation				
	T0	T1	T2	T3	T4
Muscle soreness	X	X	X	X	X
Range of motion	X	X	X	X	X
Pressure pain threshold	X	X	X	X	X
Vertical jump	X		X		X
Isokinetic	X		X		X



Note. The “x” indicates that testing has taken place at this time evaluation.

Figure 11 – Criterion Measure Testing according time evaluation and experiment flow-chart.

Pre-intervention phase: After completing a previous questionnaire all patients were registered into a database. In this phase, the study staff guided the patient through the consent process in which patients were informed about the study design. Once written consent was obtained, participants were randomly assigned to one of three groups (VA vs. SA vs. CG), demographic data was collected and leg dominance determinate. After that, these individuals were evaluated to establish a baseline [Time 0 (T0)] in 6 separate main outcome variables on non-dominant leg (Newton et al., 2012) in the following order: muscle soreness, range of motion, pressure pain threshold, vertical jump and isokinetic (average quadriceps peak torque; quadriceps peak torque/body weight).

EIMD protocol phase: In these phase, the participants performed the EIMD protocol.

Intervention phase: In this phase was carried out the second evaluation [Time 1 (T1)], which consisted only in muscle soreness (MS), range of motion (ROM) and pressure pain threshold (PPT). In this evaluation vertical jump (VJ) and isokinetic were not measured because this outcome measures may exacerbate muscle injury and it is not necessary measure it twice in a few minutes because on the third evaluation [Time 2 (T2)] they repeated all the measures. Between T1 and T2 they underwent acupuncture according the group they belong. In the CG they don’t underwent acupuncture but wait 2 minutes between evaluations because it was the necessary time to apply this acupuncture technique. Then, 24 hours later, individuals made the fourth evaluation [Time 3 (T3)] which was the same as T1. Subsequently they were submitted to acupuncture according group or wait 2 minutes to following made the final evaluation [Time 4 (T4)] which measure all six main outcome measures. A full description of the methods used to analyze the data of the present study is outlined in procedures.

7.3 Protocol treatment

After randomly distributed for the three groups, participants received the following treatment protocol for each group:

Verum acupuncture group (VA) – Acupuncture with “Leopard spot” technique. Treatment with S34, S36, and H3, on the non-dominant limb with an insulin needle.

Sham acupuncture group (SA) – Acupuncture with “Leopard spot” technique. Treatment with three other points (points with no therapeutic evidence that were not associated with any conduit), on the non-dominant limb with an insulin needle.

Control group (CG) – Not received treatment.

For the execution of acupuncture protocols, all participants were positioned in the supine position and received treatment at total rest. All participants were blinded regarding the treatment and didn`t know to which group they were allocated (Witt, et al., 2005). Once properly disinfect the skin, the participants were intervened in points according to the group. The points were selected by expert’s practitioners at the Institute of Biomedical Sciences Abel Salazar - Universidade do Porto. The selection of points in VA was based on the Heidelberg model of Traditional Chinese Medicine (Greten, 2010). The “Leopard spot” technique consisted of 5 quick penetrations on skin (Hauer, et al., 2011; Nabeta, and Kawakita, 2002) in the selected points The penetration depth was controlled by the size of the blade of the insulin needles (Hauer, et al., 2011).

Acupuncture Points

Verum points

S34 – *Monticulus septi (Liangqiu)*: is located 2 cun above the superior pole of the patella and aligned with the lateral edge of the patella, feeling with palpation as a groove in the vastus lateralis (Porkert, Hempen and Pao, 1995; Focks, März and Hosbach, 2008; Hempen, Chow, 2006). The location of this point is illustrated in Figure 12. This point is described as the point "rimicum" on the conduit of the Stomach. This term arises due to the ability of the rimic points to become dynamic “Qi” along the conduit when, for some reason, there arises congestion or “Qi” stasis (Porkert, Hempen and Pao, 1995; Hempen, Chow, 2006). Thus, the S34 plays an important role, particularly in pain management throughout the conduit (Greten, 2010). In addition to local analgesic effect (mainly in disorders at knee) and distal (in the path of the conduit) this point is still traditionally used in muscle weakness and neurological changes in lower limb (Hauer, K., et al, 2011), all problems in DOMS. It has also indicated in presence of *algor* patterns (decreased functional microcirculation), cold extremities and lower digestive tract

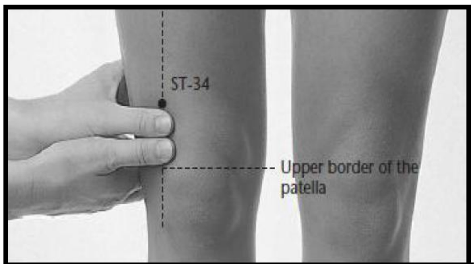


Figure 12 – S34 localization (Focks, März and Hosbach, 2008)

disorders such as: pain, convulsions or spasms of the stomach, gastritis and diarrhea (Porkert, Hempen and Pao, 1995; Hempen, Chow, 2006), as well as stimulation of metabolic functions (Hempen, Chow, 2006; Tong, et al., 2011).

S36 - *Vicus tertius pedis (Zusanli)*: is located 3 cun below lower border of the patella, 1cun from the front edge of the tibia, on the fibular side, at the level of the tibia tuberosity (Focks, März and Hosbach, 2008). *Vicus* refers to a place and a chain of post stations where the horses can be exchanged and the people can eat and recover. Suppletive effect of S36 is a common everyday application, e.g. for fatigue, hard work and depletion, and it has a couple of interesting effects on trauma on the feet after prolonged walking or ever after distortion of the exterior ligaments and therefore in DOMS associated pain and fatigue. The S36 is the conjunctory of the stomach conduit. It is allocated to the phase of Earth. It has a vast body of usage in the context as a conjunctory. It is the major stabilizing point of the body. The reason for this is that the phase Earth is the most regulatory phase in the body and, as we have discussed before, the extimal conjunctories are more in use for the above-named reasons (Greten, 2012). This point is a conjunctorium of the Stomach conduit- Earth point on Earth conduit, regulates the relation between the vegetative capacity to function (“Qi”) and the functional capacity bond to the body fluids (“Xue”), Eu-regulation: stabilizes the Centre (Stomach and Lional orb) and acts in all forms of hidrostasis Humor (Greten, 2010).

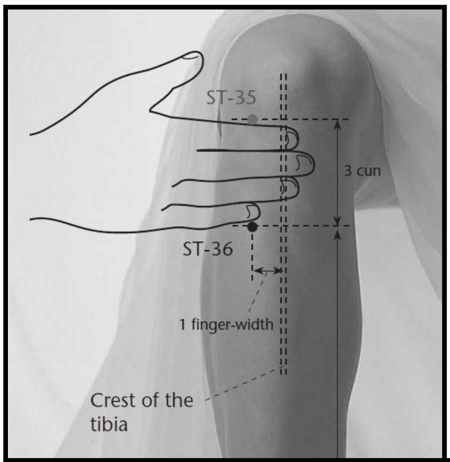


Figure 13 – S36 localization (Focks, März and Hosbach, 2008)

H3 – *Impedimentale major (Tai Chong)*: Is located between the metatarsals of the 1st and 2nd toe, in a depression about 1,5 cun proximal to the terminal phalanx of the big toe (Focks, März and Hosbach, 2008). This point is the inductory of the hepatic orb, an intimal orb, and therefore it is allocated to the phase Wood. *Impedimentale* literally means a broad road with much traffic. This indicates that much “Qi” can flow or can be mobilized to flow through this point (hepatic “motorway”). This is e.g. important for elderly persons whom we want

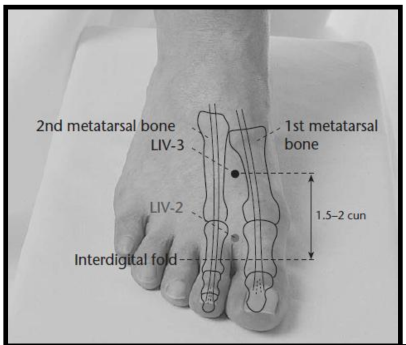


Figure 14 – H3 localization (Focks, März and Hosbach, 2008)

to mobilize (suppletio). However, this point mostly is dispulsed as in practice an over-expression of the phase Wood is seen much more frequently. By this we limit the reaction to provide potential in stress. This explains its action in uprising yang. H3 is also the point where the original “Qi” can be reached. Its daily usage is directed to hepatic actions within body and therefore as an action in the muscle tissue. Therefore, the diagnostic scenario on which we would use this point is mainly repletive and it is also the scenario of *calor* as repletion corresponds to *calor* and *calor* itself is a hepatic sign. The usage of H3 of course also is good against constriction of the conduit system. This makes it possible to take this therapy of the “four gates”, the general measure in conditions in which the pain is everywhere and an allocation to a specific conduit is not easy (Greten, 2012). This point has some effects like proven action in conventional medicine like increases the plasmatic level of endothelin, and ameliorates hypertension (Focks, März and Hosbach, 2008). In TCM is Inductorium of the hepatic conduit-Earth point (orthopathy) on a wood conduit-potential, i.e. brings eu regulation to the potential, is a point of hepatic “Qi” originale (stabilizes and regulates hepatic and felleal orb), regulates and reduces the excess activity of “Xue” (Greten, 2009).

Sham points

In SA group were used points with no therapeutic evidence that were not associated with any conduit and aren't acupuncture points. The points were:

Sham point number 1: located laterally, in the same alignment point S34, between the Felleal and Vesical conduits.

Sham point number 2:

Located 5 cun below the point Vesical 57.

Sham point number 3:

Located 6 cun below the point Vesical 57.

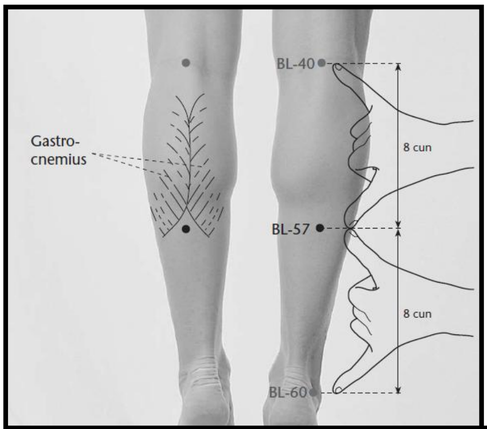


Figure 15 – V57 localization (Focks, März and Hosbach, 2008).

8. Sample

The sample of this study was one of convenience, in a total of forty five volunteers (mean ± s age 25,38 ± 4,77 years; weight 65,76 ± 9,88 kg; height 169 ± 0,09 cm and body mass index 22,94 ± 2,51 Kg/m^2 (Table 2), of both genders, after completing a previous questionnaire and providing written informed consent.

Table 2 - Sample data characterization.

Variables	N	Gender		Age (years)	Weight (kg)	Height (cm)	BMI (Kg/m^2)
		Male	Female				
VA	15	8	7	24,20 ± 4,04	64,60 ± 8,24	169 ± 0,09	22,45 ± 1,63
SA	15	7	8	26,13 ± 4,37	69,63 ± 9,96	172 ± 0,09	23,42 ± 2,44
CG	15	4	11	25,80 ± 5,81	62,93 ± 10,61	166 ± 0,10	22,94 ± 3,28
Total	45	19	26	25,38 ± 4,77	65,76 ± 9,88	169 ± 0,09	22,94 ± 2,51

The subjects were randomly divided in three groups with 15 elements each using a software available *at www.graphpad.com/quickcals*: a *verum* acupuncture group (VA), a sham acupuncture group (SA) and a control group (CG), as can be seen in figure 16. There was no loss in the follow up (0%).

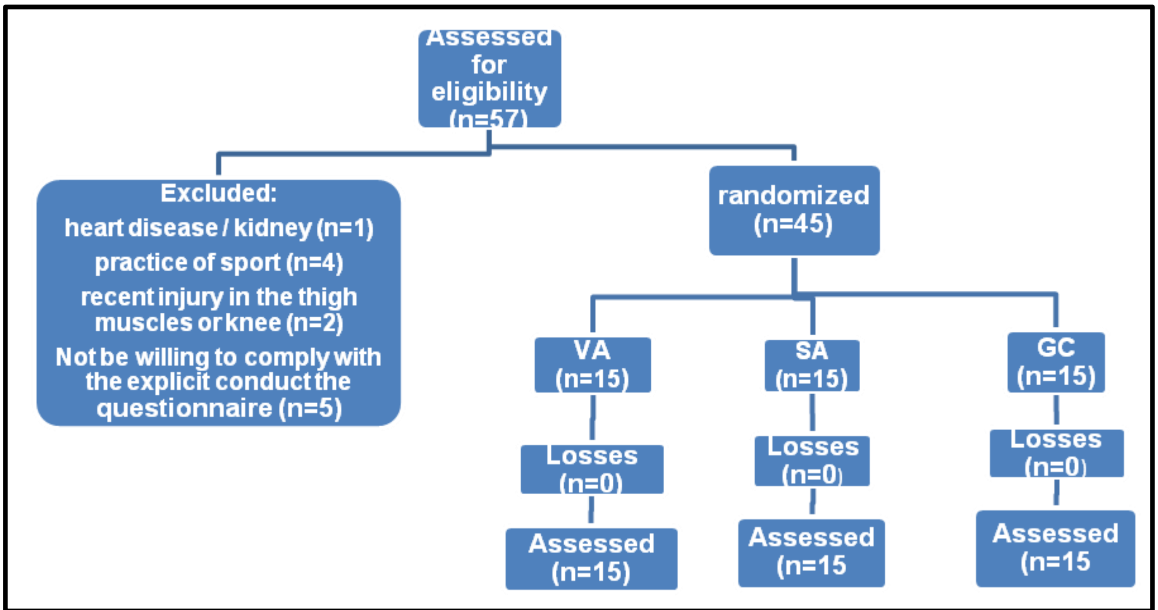


Figure 16 - Sample diagram.

The individuals belonging to the sample were evaluated in 6 main separate outcome variables (muscle soreness; pressure pain threshold; range of motion; vertical jump; isokinetic (quadriceps average peak torque; quadriceps peak torque/body weight) with repeated measures over five time points [Baseline, after EIMD protocol after 1º treatment, before 2º treatment (24h), after 2º treatment (24h)] on the non-dominant leg (Newton et al., 2012). Each participant was subject to an EIMD protocol which has be previously shown to cause significant elevation in muscle damage indices (Miyama and Nosaka, 2004a; Goodall and Howatson, 2008; Howatson et al. 2012).

9. Eligibility criteria

9.1. General aspects

Eligibility criteria were developed in order to establish a homogenous group of patients.

9.1.1. Inclusion criteria

The study included subjects from both genders, aged between eighteen and forty years, without previous history of hamstring or quadriceps muscle injury, without any previously medical diagnosed musculoskeletal pathologies in the lower limb or renal, cardiac, metabolic, and endocrine disorders which might inhibit the performance of physical exercise (Abad et al., 2010; Hilbert et al., 2003; Milias et al., 2005).

9.1.2. Exclusion criteria

Subjects had to be excluded from the study if they were athletes, individuals treated with anti-inflammatory AID’s, pain and muscle relaxants and individuals who had performed vigorous physical exercise within seven days prior to the protocol were excluded from the study (Abad et al., 2010; Hilbert et al., 2003; Milias et al., 2005). Were also excluded woman’s with menstruation, pregnants, participants with intense fear of needles and any type of drugs consumption (Itoh et al., 2008). Participants who drank beverages containing caffeine or alcohol in a period of less than 12 hours prior to the measurements were excluded (Hübscher et al., 2008).

10. Instruments

For the purpose of the study the following instruments were used:

A questionnaire developed for this purpose, in order to characterize and exclude possible subjects from the sample (**Annex A**);

A stadiometer (Seca® Medical Scales and Measuring Systems®, Birmingham, United Kingdom) to measure the height of the participants;

A scale (Seca® Medical Scales and Measuring Systems®, Birmingham, United Kingdom) to evaluate the weight of the participants;

A cycle-ergometer (BH Fitness®, Confort Evolution) to perform the warming-up prior to the performance of isokinetic evaluation;

A surgical black marker to mark the point in the skin from one day trough the other, in pressure pain threshold measurements;

An algometer (Wagner Fdix®, USA) to measure the pressure pain threshold which shows values inter-observer of 0.95 and intra-observer of 0.89 in line Aminian-Far et al. (2011);

The visual analogic scale (VAS), consisting of a straight measurable line ranging from 0 to 100 mm, which allows the quantification of pain was used in this study to measure muscle soreness. According to the General Directorate of Health, the VAS is an internationally validated scale used to measure pain intensity (Sprott et al., 1998; Marques et al., 2008; Baranowsky et al., 2009; Langhorst et al., 2010; Itoh and Kitakoji, 2010; DGS, 2003) converted into a numerical scale for registration (DGS, 2003), since it can detect small differences in pain intensity compared with other scales (Briganó and Macedo, 2005). It is very useful to compare the outcome of a patient with himself during a treatment, however, is not as reliable in comparing individuals with each other (Marques et al., 2008).

An ErgoJump® dynamometer (Globus®, Italy) was used in order to evaluate the explosive muscle strength of the lower limb. Bosco (1982), idealized a method, (named “di Bosco”), to evaluate the inferior limbs power, through a number of jumps made on a special carpet: The Ergojump Bosco System. The computer associated with it calculates the time of touch on the soil, the flight time and the jump distance, in height in order to obtain important information about explosive power and reactive power. This equipment allows several tests of impulsion power and was choose one of them: a vertical jump test from a static position (Squat Jump – SJ).

A Biodex System 4® isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA), in order to evaluate the quadriceps average peak torque (AVG PT) and quadriceps peak torque/body weight (PT/BW), which owns a high reliability of 0,99, tested for Biodex

3 (Drouin et al., 2004) and validity. The isokinetic dynamometry is an important requirement on the neuromuscular evaluation. Dynamometry gives a valid, sensitive, specific and reliable evaluation. A lot of advantages were described on the isokinetic dynamometer use regarding the muscular performance, such as, the peak torque (PT), PT/BW, AVG PT, time to peak torque, the agonist/antagonist reasons and total work (Ellenbecker and Davies, 2000). The isokinetic evaluation of the inferior limbs muscular power has been used many times to objectively assess the muscular performance. In this sense, it contributes to the prevention, diagnostic, rehabilitation and sport performance increase (Brown, 2000; Iga, George, Lees and Reilly, 2009; Lehance, Binet, Bury and Croisier, 2009; Schiltz et al., 2009). The utility of the isokinetic dynamometry to evaluate deficits and imbalances of muscular power is consensual (Croisier, 2004). According to Croisier, Ganteaume and Ferret (2005) muscular power and balance have an important role in certain acute muscular injuries. Literature postulated that muscular tension derives from varied causes, such as, inadequate flexibility, muscular weakness and muscular imbalances, wrong warm-up, excessive fatigue, bad posture, dyssynergic contractions, poly articulated characteristics and rapid muscle fibers percentage (Croisier, 2004). The isokinetic dynamometer implies that the angular speed is constant. This way, they allow the individual to exercise his maximum strength in the entire range of motion angles at a predetermined speed, when the member's angular variation exceeds or surpasses the pre-established speed, the dynamometer produces an opposite power which maintains the constant member speed. The resistance is electronically controlled and in each angular position, the dynamometer offers a resistance that is proportional to the power developed by the individual (Mil-Homens, 1996). Therefore, it is the member that moves itself on a constant angular speed and not the muscular contraction that is constant. A constant angular movement is not followed by a shortening and constant muscular contraction. The use of the isokinetic dynamometer imposes an intensive muscular work, and, therefore, it creates a marked heart rate and arterial tension increment. Due to maximal exercises made at high speeds, the most requested metabolic pathway is the anaerobic one, with the formation of lactic acid. So, the individual should make an active recovery after the exercise, so that the oxygen consumption is able to diminish the lactate concentrations. The most common brands are Biodex®, Cybex® and Lido®. The PT is one of the measurements which has most relevance and has been used most frequently on scientific studies and, according to literature, this isokinetic measurement is a precise and reproducible variable, becoming a reference to all the isokinetic evaluations (Brown, 2000; Croisier, 2004; Dvir, 2004). PT represents the highest value of torque produced by the muscle, i.e., indicating a greater ability to produce force, similar to one repetition maximum (1RM) in isotonic conditions. AVG PT represents the average of PT results in

each evaluation and PT/BW represents a ratio expressed in % of the maximum torque normalized to the bodyweight of the subject under test. It is an important and relevant value when comparing subjects with different weights from each other and is connected to the functional activities (Carvalho and Puga, 2010). As far as the validity of the test equipment concerns, Drouin et al. (2004) showed that the isokinetic dynamometer Biodex system 3 pro is a valid and reliable tool. The system used on this study (Biodex system 4) just suffered some minor changes and therefore it is legitimate to assume that the validity and reliability of it remains unchanged.

A ball was used to identify the non-dominant limb (Lucena et al., 2010).

A goniometer (MSD Europe BVBA®) which is an instrument consisting of a body similar to a protractor with two arms. An arm is fixed with respect to the protactor and the other is mobile. The arms are articulated by an axis. This device is clinically used to quantify the joint range of motion (Vieira, 2002). The complexity of human joint motion requires that care be taken to align the axis of the goniometer with the joint axis. Some of the questions raised regarding the validity of the goniometer respect, the fact that the joint axis are not fixed and varies according to the position of the range of movement, beyond that, when aligned with the joint axis, the goniometer arms often are not aligned with the jointed bone segments (Vieira, 2002). In this study, there was on the part of all participants utmost care in the placement of the instrument as well as the correction and elimination of possible compensation by the patient.

Insulin needles BD Micro-Fine® +: 0,25 (31G) x 8mm (Certification “Type A” EN ISSO 11608-2) were used to perform “leopard spot” technique because as with this kind of needles the depth of puncture can be easily controlled and provoke the bleeding (Hauer, et al., 2011).

A Step with 20 risers to perform the EIMD protocol.

A Smartphone Samsung Galaxy S3 for photographs and movies.

11. Procedures

Following the authorization of the Director of Hospital-School of Fernando Pessoa University and the department chief of the Physical Medicine and Rehabilitation department (**Annex C**) and the approval of the Ethical Committee (**Annex D**), all the subjects were subject through a questionnaire, in order to characterize the sample, to identify possible exclusion criteria and to motivate and increase participant adherence to the study. Previously to data collection, the participants were informed about the aim of the study, procedures, and were given all additional clarifications on the doubts that may arise, to avoid failures during the collection, thus ensuring the standardization of procedures. Participants were also encouraged not to treat the pain when it arises, either trough drugs or other treatments (like ice, warm water immersion or stretching), so that it will not tamper the results and advised not to take any vitamin supplement, caffeine or alcohol during the study (Goldfarb,1999; Van Someren et al., 2005; Rawson et al., 2001; Lembke et al, 2014; Baum et al, 2013; Caitlin et al, 2013). Participants were informed that they should not talk with each other about the sample procedures, in order to maintain themselves blind to the results of study. After that, biometric data collection, muscle soreness, pressure pain threshold, range of motion, vertical jump and Isokinetic evaluations were performed. After this first evaluation (T0) of all 6 principal outcome measures, EIMD protocol was performed.

11.1. Biometric data collection

After the biometric data collection, weight and height of participants was accessed to calculate body mass index (BMI) and age in order to guarantee the homogeneity of the participants. Leg dominance was then assessed by asking the participant to kick a ball to the researcher, after having received it the same way (Lucena et al., 2010).

11.2. Muscle soreness

A visual analog scale that had a 100-mm line with “no pain” on one end (0) and “extremely painful” on the other end (100) was used (**Annex E**) to evaluate the perceived muscle soreness (MS) ratings for the knee extensors during a 5 seconds squat position (Miyama and Nosaka, 2004a), as we can see in figure 17.

Figure 17 – Squat position for measure muscle soreness.

11.3. Pressure pain threshold

Figure 18 – PPT measure.

The pressure pain threshold (PPT) has been defined as the lowest stimulus intensity at which an individual perceives mechanical pain (Vanderweeen et al., 1996). PPTs provide a means to evaluate mechanical hyperalgesia, where a reduction in PPT values relative to baseline indicates mechanical hyperalgesia (Frey Law et al., 2008).

The PPT was assessed using a pressure algometer (Wagner Fdix®, USA). Constant pressure was exerted until the participant feel the lowest stimulus intensity at which an individual perceives mechanical pain at one reference point marked on the thigh along a line drawn from the anterior superior iliac spines to the superior pole of the patella. The point was at 5 cm above the superior pole of the patella (representing the musculotendinous junction) (Figure 18) (Sellwood et al., 2007).

The locations were marked to ensure that PPT was recorded at the same locations on all two days. The PPT recordings were carried out in a seated position with a 90˚ angle in the hip and knee joint and performed three times at each location, starting with the most distal point and ending with the most proximal point for both recordings. The best result of PPT of the 3 recordings at each location was used in further analysis. During PPT recordings, the algometry was applied perpendicular to the skin (Aminiain-Far et al., 2011; Law et al., 2008).

The subjects were instructed to say ‘yes’ as soon as the pressure exerted by the algometer became ‘slightly unpleasant’, as has been proposed in similar studies (Vanderween et al. 1996; Dhondt et al.1999) and was preferred to using the expression ‘pain’ alone.

11.4. Range of Motion (ROM)

For the measurement of knee flexion ROM, subjects laid prone on a massage bed with both knees fully extended. From this position subjects were asked to fully flex their non dominant knee. The knee joint angle was determined by using a goniometer and universal landmarks (lateral epicondyle of the femur, lateral malleolus and greater trochanter) to ensure alignment (Tokmakidis et al., 2003). Landmarks were marked with a semi-permanent pen to ensure consistency on subsequent measures, 3 measurements were performed and the average was reported (Goodall and Howatson, 2008).

11.5. Vertical Jump

The vertical jump (VJ) performance was assessed using the ErgoJump® dynamometer (Globus®, Italy), which participants assumed a squat-jump test position. This test consists on the execution of a jump from a flexion knee position at 90º without previous countermovement (Figure 19). The hands are holding the pelvic girdle. The trunk is on a vertical position. The knees should remain at 180º (extension) on the flight movement, and the feet contact the soil on hyperextension. After contacting the soil, the participant may flex the inferior limbs up to a 90º angle (knees). Each participant was previously familiarized with the test procedure prior to the recorded efforts and received strong verbal encouragement for each attempt (Markovic et al., 2004). The subjects were then asked to perform 3 jumps with 2 to 3 minutes between jumps and it was chosen the best of the 3. The flight time was registered during the jump, and it was later calculated the reached height by the gravity center, or real impulsion which is the difference between the maximum elevation of the gravity center and the starting position, frequently calculated through the formula proposed by Bosco (1981): h= tv2 x 1.226, and later by Bosco et al., (1983): H = (g x tv2) / 8 where h is related with the jump height (centimeters); g means the gravity acceleration (9.81 m/s2); and tv is the flight time (meters per second).

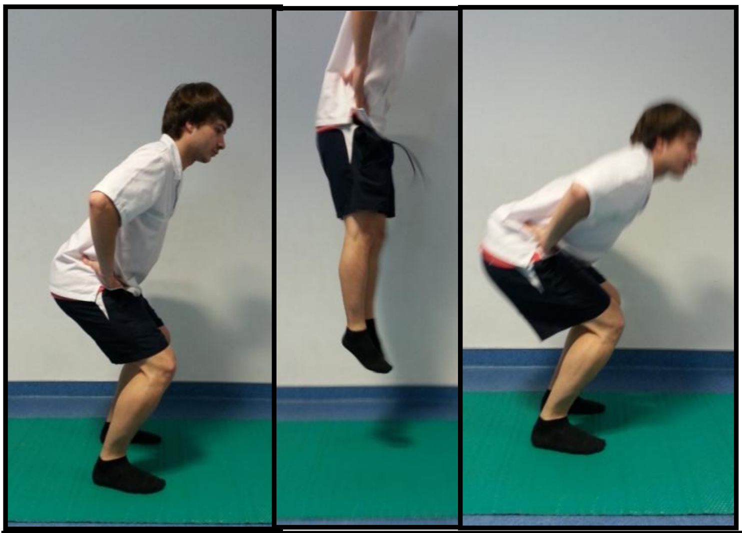


Figure 19 – Participant performing the squat jump test.

11.6. Isokinetic

After the above mentioned measurements, participants warmed-up in the cycle-ergometer for 5 minutes, with a resistance equivalent to 2% of body weight, at a moderate power (50W) to avoid fatigue (Aminiain-Far et al., 2011).

After the warming-up, the participants assumed a sitting position with the popliteal fossa 2 cm outside the edge of the chair of the isokinetic dynamometer, and stabilizations were performed in the trunk, pelvis and 1/3 distal to the thigh, to avoid compensations and isolate the single degree of freedom of the knee. The axis of the dynamometer was visually aligned along the axis of the knee joint, and the resistance application point was placed 2cm above the malleolus of the tibio-tarsal joint and secured with velcro bands (Figure 20).

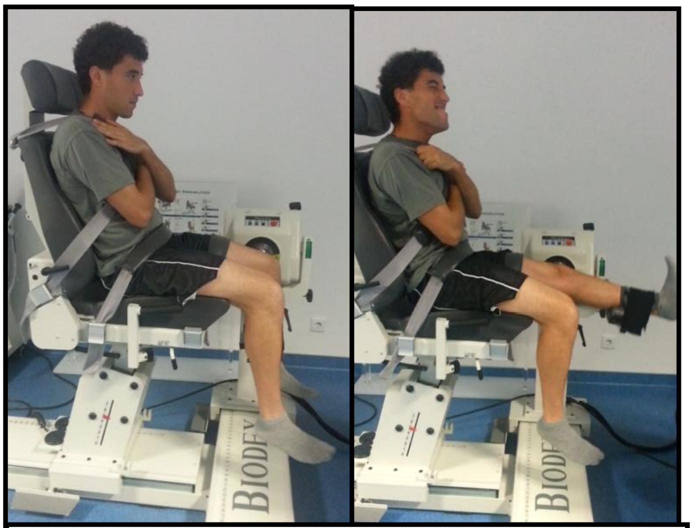


Figure 20 – Participant at start position at left and performing isokinetic evaluation at right.

All participants measured the maximum extension and flexion of 90º, as well as it was measured the weight of the limb in study, in order to fix PT due to gravity. Participants performed the evaluation which consists of 3 sets of 10 maximal concentric contractions of the quadriceps and hamstrings, unilaterally and in the non-dominant limb, at a running speed of 60º/s, with 90s intervals between sets, in a range between 90º and 0º.Visual biofeedback, verbal commands and patient positioning were uniform for all groups in the study during the protocol (Barroso et al., 2010; Drouin et al., 2004; Hilbert et al., 2003; Hunter et al., 2012).

The chosen stabilization had the purpose of maintain a minimum, or even to exclude, the other muscles contributions (Dvir, 2004). The gravity correction was made to eliminate the gravity effect on PT values in knee flexion and extension movements (Brown, 2000; Dvir, 2004). Before the isokinetic evaluation, the participants made 5 submaximal repetitions to guarantee a good familiarization with the speed of the test (Brown, 2000; Dvir, 2004). A 90s rest period between each set was used, since this value was reported as the ideal one (Brown, 2000). Encouragement and verbal commands was patronized in order to create a consistent test environment (Campenella, Mattacola and Kimura, 2000).

11.7. Exercise-induced muscle damage

Each participant was subject to an EIMD, which subjects dropped from a height of 0.6m step, and jumped upward maximally immediately after landing from the box and landed on the surface again after the vertical jump. To perform the next drop jump, subjects had to climb two steps onto the step. Five sets of 20 drop jumps were performed with a 10 s interval between jumps, and a 2 min rest period was given between sets. Subjects performed drop Jumps with barefoot, because it has been reported that biomechanical factors are influenced dramatically by shoes (Wit et al., 2000; Ogon et al., 2001), and comparisons between bouts were thought to be easier by eliminating the effect of shoes. The investigators carefully supervised the exercise to eliminate the risks for unexpected injury. At the end of this protocol participants were advised to drink water to prevent renal failure due to rhabdomyolysis (Chen et al., 2012; Jonhagen et al., 2004).This protocol has been previously shown to cause significant elevation in muscle damage indices and produce DOMS (Miyama and Nosaka, 2004a; Goodall and Howatson, 2008; Howatson et al. 2012).

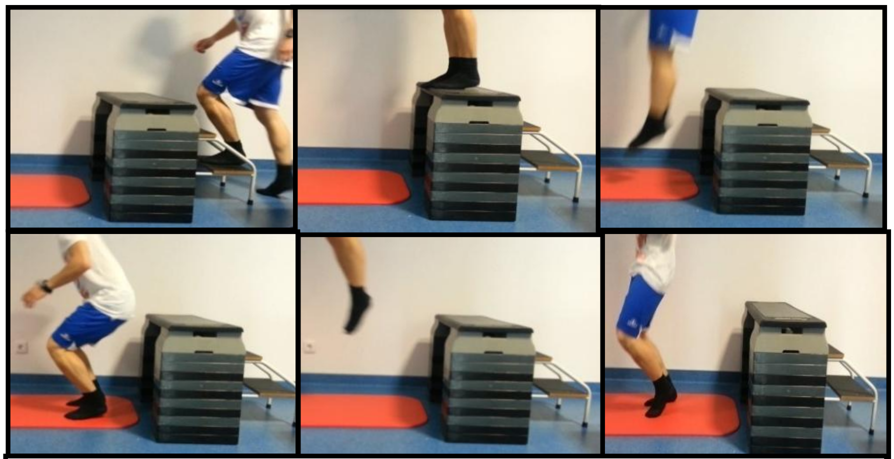


Figure 21 – Participant performing EIMD. Starts from up to down and left to right.

11.8. “Leopard Spot” technique

The leopard spot technique is one of the five puncture techniques described on the classic TCM literature. Also known as “sparrow-pecking technique”, it basically consists in fast skin penetrations on a certain acupuncture point (Hauer, et al., 2011; Nabeta, and Kawakita, 2002). For excess type syndromes, bleeding is recommended because it can drain the excess, alleviate congestion and stasis, and remove the pathogens. The function of this therapy is "to drain *calor* or “quicken” the “Xue” and “Qi” and relieve local “congestion" (Wiseman and Ellis, 1985). While standard acupuncture therapy is depicted as being effective, in part, by releasing various transmitter substances (i.e., endorphins), by stimulating local blood flow (i.e., by dilating vessels), and by producing changes in the brain that may have both systemic and highly specific effects, letting out a small amount of blood (usually just a few drops) remains without a suitable explanation for the potent effects claimed. The technique used to let out the blood is one of quick and light pricking to pierce the skin and vein.

12. Statistical analyses

The data collected were processed using the following statistical analysis software:
Microsoft Excel 2010 and *IBM SPSS Statistics 22*.
The Microsoft Excel 2010 program, was used to calculate the descriptive measurements, mean and standard deviations of the sample characteristics and to create graphics of the 6 outcome measures used in this study.
Subsequently, the IBM SPSS Statistics 22 program was used to perform inductive analysis of the data. First the Shapiro-Wilks test was used for assessment of normality as the sample had a sample size as there wasn´t a normal distribution along the groups, non-parametric tests were used. A Kruskal-Wallis test with for analysis of differences between groups in the different moments was performed along with a Friedman test with a Bonferroni post-hoc test, to assess differences within the group along the different moments.

Chapter 3 - Results

Results

At baseline there wasn´t statistically significant differences for the MS, ROM, PT/BW and AVG PT, with p values above 0,05 meaning there is homogeneity between the groups at T0, except for VJ parameter in the CG and VA and for PPT parameter in the VA and SA groups which were statistically different to begin with.

Muscle Soreness

The MS analysis with the use of the VAS reflected the subjective perception by the subjects and may also reflect a central effect of muscle fatigue.

All groups showed statistically significant changes in MS scores along T0 to T4 assessment times (Table 3), showing an effect of EIMD on MS.

Table 3.Differences within and between the groups (VA, SA and CG) in the different moments in MS (VAS).

VA	mean ±SD	p within the group	SA	mean ±SD	p within the group	CG	mean ±SD	p within the group	p between groups
T0	0 ± 0		T0	0± 0		T0	0 ± 0		1,000
T1	3,07 ± 2,09		T1	3,00 ± 1,96		T1	3,20 ± 2,11		0,953
T2	1,67 ±1,80	0,000	T2	2,47 ± 1,73	0,270	T2	3,20 ± 2,11	0,000	0,079
T3	3,13 ± 2,07		T3	3,93 ± 2,46		T3	4,27 ± 2,19		0,324
T4	2,07 ± 1,71		T4	3,27± 2,49		T4	4,27 ± 2,19		0,027

VA (Verum Acupuncture Group) SA(Sham Acupuncture Group) CG (Control Group).Values expressed as mean ± standard deviation. The Friedman test with a Bonferroni post-hoc test was used for access differences between the different moments for a specific group. The Kruskal-Wallis test was used o access differences between groups in the different moments.

When we compared the different groups in the different moments we observed a statistically significant difference in MS at T4 assessment time (p=0,027) when we compared all 3 groups. A group by group analysis in the different moments showed a statistically significant difference between the CG and VA groups at T2 (p=0,032) and T4 (p=0,01) moments, with an increase in the MS in the T4 time of 42.7% in the CG group versus a increase of only 20,7% in the VA group (Table 4; Figure 22).

Table 4.Differences between the groups (VA, SA and CG) in the different moments in MS (VAS).

VA vs. SA	p between VA vs. SA	VA vs. CG	p between VA vs. CG	CG vs. SA	p between CG vs. SA
T0	1,000	T0	1,000	T0	1,000
T1	0,983	T1	0,767	T1	0,816
T2	0,145	T2	0,032 *	T2	0,342
T3	0,322	T3	0,156	T3	0,528
T4	0,164	T4	0,010 *	T4	0,136

VA (Verum Acupuncture Group) SA(Sham Acupuncture Group) CG (Control Group).The Kruskal-Wallis test was used o access differences between groups in the different moments. Significant p values (p<0,05), * vs. CG (p<0.05).

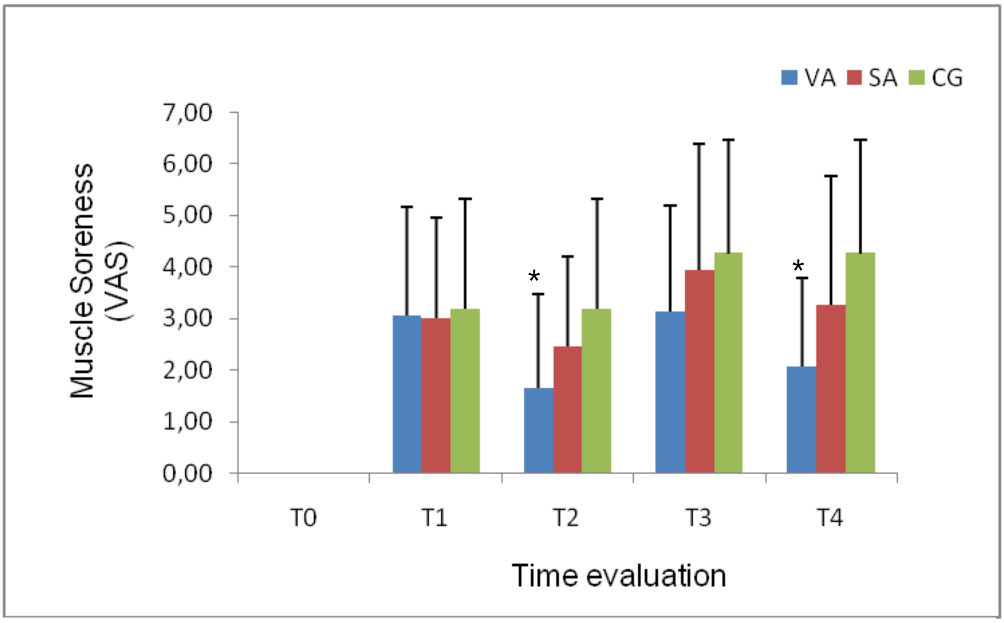


Figure 22 - MS scores of the VA, SA and CG groups (mean ±SD). * vs. CG ($p<0.05$).

The absence of significant differences between the CG and SA groups showed that the SA group did not produce any significant effects in DOMS associated MS, although some effects should exist as there wasn´t any significant differences between the VA and SA groups.

Pressure Pain Threshold

The PPT was a more quantitative parameter that reflected a more local effect of EIMD (Table 5).

Table 5.Differences within and between the groups (VA, SA and CG) in the different moments in PPT (kgf/cm^2).

VA	mean ±SD	p within the group	SA	mean ±SD	p within the group	CG	mean ±SD	p within the group	p between groups
T0	5,85 ± 1,68		T0	4,65 ± 1,22		T0	4,84 ± 1,93		0,080
T1	5,29 ± 1,84		T1	3,94 ± 1,01		T1	4,02 ± 1,45		0,010
T2	6,99 ± 2,23	0,000	T2	4,45 ± 1,23	0,270	T2	4,01 ± 1,45	0,000	0,000
T3	5,23 ± 1,68		T3	3,90 ± 1,28		T3	3,31 ± 1,25		0,002
T4	6,71 ± 2,41		T4	4,46 ± 1,48		T4	3,30 ± 1,39		0,000

VA (Verum Acupuncture Group) SA (Sham Acupuncture Group) CG (Control Group).Values expressed as mean ± standard deviation. The Friedman test with a Bonferroni post-hoc test was used for access differences between the different moments for a specific group. The Kruskal-Wallis test was used o access differences between groups in the different moments.

When data was analyzed we found significant differences on PPT along the different moments for the different groups but with differences in evolution (Figure 23).

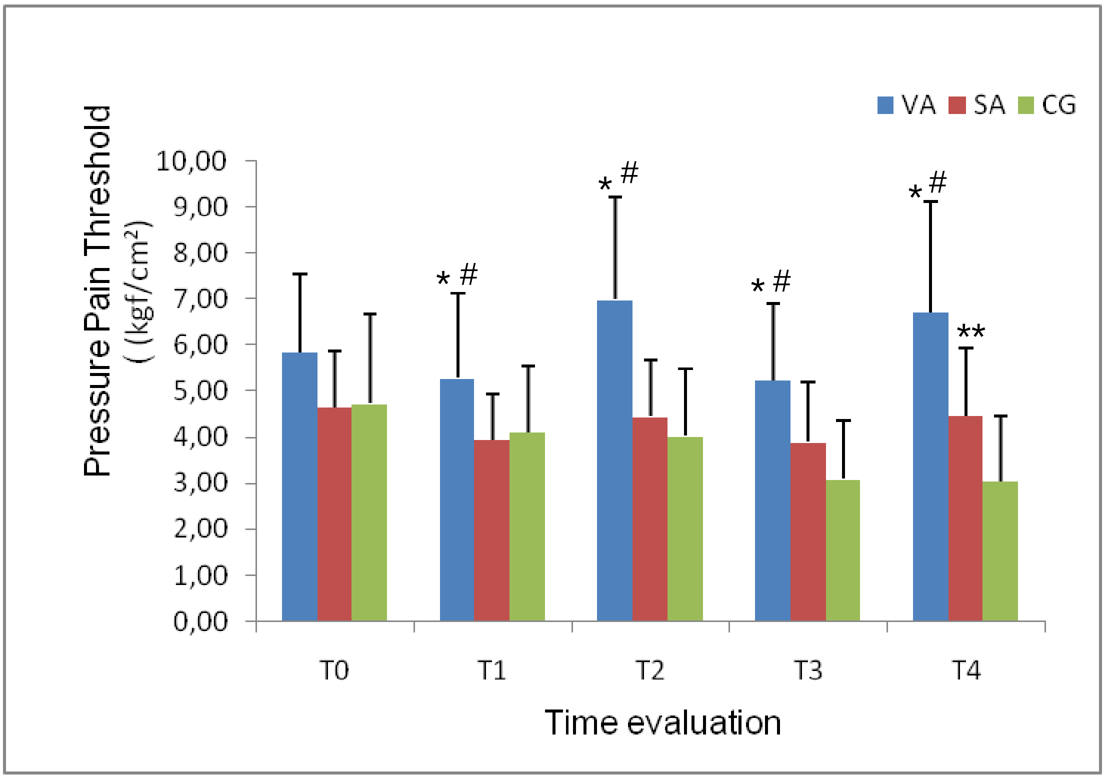


Figure 23 - PPT scores of VA, SA and CG groups (mean ±SD). * vs. CG (p<0.05), # vs. SA (p<0.05), ** SA vs. CG (p<0.05).

While in the CG we see a progressive decrease in PPT from an mean initial value (T0) of 4,84 Kgf/cm^2 to a final value of 3,30 Kgf/cm^2 (T4), the SA and VA groups showed a increase in PPT at T2 and at T4 times, suggesting an immediate and a more long term effect of acupuncture. When CG and VA groups were compared we found significant statistically differences from T1 trough T4 times. An analysis of the differences between the CG and SA groups showed differences only for the T4 time (p=0,032) (Table 6).

Table 6.Differences between the groups (VA, SA and CG) in the different moments in PPT (kgf/cm^2).

VA vs. SA	p between VA vs. SA	VA vs. CG	p between VA vs. CG	CG vs. SA	p between CG vs. SA
T0	0,025 *	T0	0,116	T0	0,930
T1	0,008 *	T1	0,011 #	T1	0,965
T2	0,001 *	T2	0,001 #	T2	0,190
T3	0,026 *	T3	0,001 #	T3	0,070
T4	0,003 *	T4	0,000 #	T4	0,032 **

VA (Verum Acupuncture Group) SA(Sham Acupuncture Group) CG (Control Group).The Kruskal-Wallis test was used o access differences between groups in the different moments. Significant p values (p<0,05), * vs. CG (p<0.05), # vs. SA (p<0.05), ** SA vs. CG (p<0.05).

Despite always been statistically different every time, at T4, and comparing to T0, the VA group showed a increase in PPT of 6%, while the SA and CG showed a decrease in PPT of -4,06% and -35,5%, respectively.

As the VA group showed the biggest increase PPT, despite the initial differences this suggests an increase effect for the VA group for this outcome measure.

Range Of Motion

All groups showed statistically significant changes in ROM scores along T0 to T4 assessment times (Table 7), showing an effect of EIMD on ROM.

Table 7.Differences within and between the groups (VA, SA and CG) in the different moments in ROM (º).

VA	mean ±SD	p within the group	SA	mean ±SD	p within the group	CG	mean ±SD	p within the group	p between groups
T0	134,80 ± 5,35	0,000	T0	133,27 ± 8,75	0,000	T0	131,60 ± 7,37	0,001	0,359
T1	133,73 ± 4,89		T1	132,33 ± 7,60		T1	130,60 ± 7,46		0,427
T2	134,60 ±5,25		T2	132,73 ± 7,83		T2	130,73 ± 7,46		0,310
T3	134,20 ± 5,14		T3	132,40 ± 7,71		T3	130,93 ± 7,34		0,362
T4	134,67± 5,29		T4	132,73 ± 8,01		T4	130,93 ± 7,34		0,319

VA (Verum Acupuncture Group) SA (Sham Acupuncture Group) CG (Control Group).Values expressed as mean ± standard deviation. The Friedman test with a Bonferroni post-hoc test was used for access differences between the different moments for a specific group. The Kruskal-Wallis test was used o access differences between groups in the different moments.

When we compared the different groups in the different moments we observed a not statistically significant difference in ROM at T4 assessment time (p=0,319) when we compared all 3 groups.

A group by group analysis in the different moments showed a not statistically significant difference between the VA and the CG groups in ROM at T1 through T4 assessment times (Figure 24), showing a decrease in ROM average along the 4 moments of assessment post EIMD. The VA group showed a decrease of -0.10% in ROM values between T0 and T4, while the CG group showed a decrease of -0.51% in ROM values between T0 and T4.

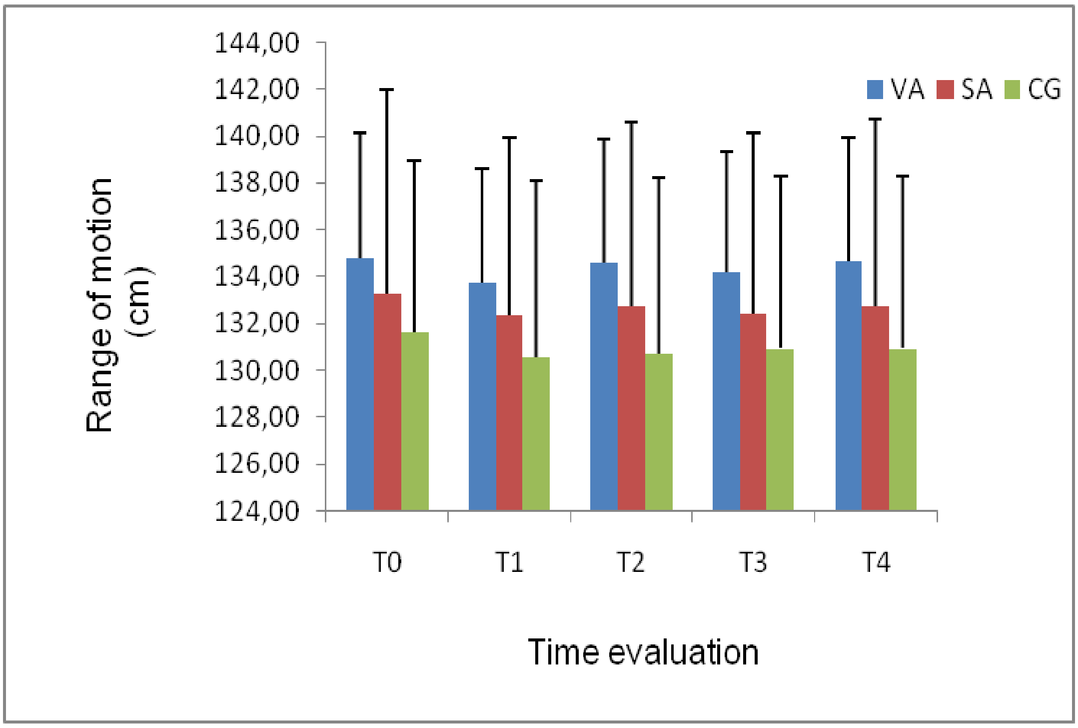


Figure 24 - ROM scores of the VA, SA and CG groups (mean ±SD).

When the CG and SA groups were compared, the same was observed. Nevertheless, the difference between ROM values in T0 and T4 moments of SA group was of -0,40%, showing a minor decrease of ROM values when comparing to the CG group but a superior decrease than the VA group.

When the VA with SA groups were compared, the same was observed when the CG and VA groups were compared, not showing any statistically differences in all times of evaluation (Table 8).

Table 8. Differences between the groups (VA, SA and CG) in the different moments in ROM (º).

VA vs. SA	p between VA vs. SA	VA vs. CG	p between VA vs. CG	CG vs. SA	p between CG vs. SA
T0	0,244	T0	0,195	T0	0,802
T1	0,279	T1	0,244	T1	0,884
T2	0,251	T2	0,137	T2	0,967
T3	0,212	T3	0,236	T3	0,803
T4	0,243	T4	0,149	T4	0,901

VA (Verum Acupuncture Group) SA(Sham Acupuncture Group) CG (Control Group).The Kruskal-Wallis test was used o access differences between groups in the different moments.

Vertical Jump

When we compared the different groups in the different moments we observed a statistically significant difference in VJ at T4 assessment time (p=0,022) when we compared all 3 groups (Table 9).

Table 9.Differences within and between the groups (VA, SA and CG) in the different moments in VJ (cm).

VA	mean ±SD	p within the group	SA	mean ±SD	p within the group	CG	mean ±SD	p within the group	p between groups
T0	33,81 ± 7,60	0,000	T0	29,31± 8,61	0,270	T0	26,97 ± 8,44	0,000	0,081
T2	33,04 ± 7,64		T2	27,86 ± 9,36		T2	25,91 ± 8,84		0,060
T4	33,25 ±7,29		T4	26,55 ± 9,12		T4	24,23 ± 8,52		0,022

VA (Verum Acupuncture Group) SA(Sham Acupuncture Group) CG (Control Group).Values expressed as mean ± standard deviation. The Friedman test with a Bonferroni post-hoc test was used for access differences between the different moments for a specific group. The Kruskal-Wallis test was used o access differences between groups in the different moments.

A group by group analysis in the different moments showed a statistically significant difference between the VA and the CG groups in VJ in all evaluation times (T0-T4), making difficult to compare this groups regarding the VJ parameters. However, comparing VJ values between T0 and T4, the CG group showed a decrease of -10,16%, while the VA group showed a decrease of only -1,66% VJ values between T0 and T4 (Table 10).

Table 10.Differences between the groups (VA, SA and CG) in the different moments in VJ (cm).

VA vs. SA	p between VA vs. SA	VA vs. CG	p between VA vs. CG	CG vs. SA	p between CG vs. SA
T0	0,178	T0	0,024 *	T0	0,468
T2	0,101	T2	0,021 *	T2	0,534
T4	0,054	T4	0,008 *	T4	0,431

VA (Verum Acupuncture Group) SA(Sham Acupuncture Group) CG (Control Group).The Kruskal-Wallis test was used o access differences between groups in the different moments. Significant p values (p<0,05), * vs. CG (p<0.05).

The absence of significant differences between the CG and SA groups (Figure 25) showed that the SA group did not produce any significant effects in DOMS associated VJ, although, some effects should exist as there wasn´t any significant differences between the VA and SA groups.

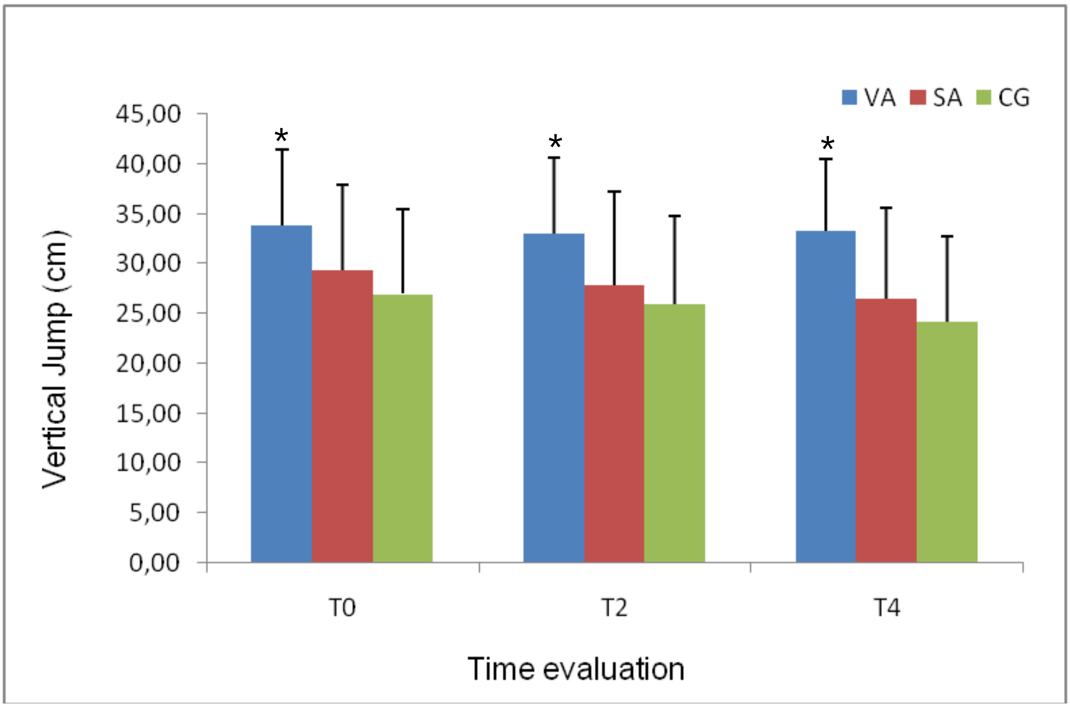


Figure 25 - VJ scores of VA, SA and CG groups (mean ±SD). * vs. CG (p<0.05).

Nevertheless, the difference between VJ values when compared T0 and T4 moments of the SA group was of -9,42%, showing a bigger decrease of VJ values comparing to the VA group but smaller decrease when compared to the CG group.

Peak Torque / Body Weight

The VA and SA groups didn´t showed any statistically significant changes in PT/BW scores along T0 to T4 assessment times (Table 11), while the CG group showed. It´s important to note that CG and SA showed a constant decrease of PT/BW along the time, while the VA group showed a little increase. However, when we compared the different groups in the different moments we did not observed a statistically significant difference in PT/BW at all assessment times, when we compared all 3 groups.

Table 11. Differences within and between the groups (VA, SA and CG) in the different moments in VJ (cm).

VA	mean ±SD	p within the group	SA	mean ±SD	p within the group	CG	mean ±SD	p within the group	p between groups
T0	251,83 ± 43,81	0,207	T0	242,35 ± 67,69	0,936	T0	238,80 ± 58,97	0,038	0,585
T2	252,45 ± 45,99		T2	229,69 ± 68,44		T2	232,23 ± 64,74		0,224
T4	252,65 ± 57,54		T4	222,55 ± 74,94		T4	222,35 ± 68,38		0,229

VA (Verum Acupuncture Group) SA(Sham Acupuncture Group) CG (Control Group).Values expressed as mean ± standard deviation. The Friedman test with a Bonferroni post-hoc test was used for access differences between the different moments for a specific group. The Kruskal-Wallis test was used o access differences between groups in the different moments.

A group by group analysis in the different moment's didn´t showed any significant differences in PT/BW at T1 through T4 assessment times. However, the VA group showed an improvement of 0,33% of the PT/BW values between T0 and T4, while the CG group showed a decrease of -6,89% of the PT/BW values between T0 and T4 (Table 12).

Table 12.Differences between the groups (VA, SA and CG) in the different moments in PT/BW (%).

VA vs. SA	p between VA vs. SA	VA vs. CG	p between VA vs. CG	CG vs. SA	p between CG vs. SA
T0	0,494	T0	0,272	T0	0,852
T2	0,120	T2	0,178	T2	0,633
T4	0,152	T4	0,130	T4	0,787

VA (Verum Acupuncture Group) SA(Sham Acupuncture Group) CG (Control Group).The Kruskal-Wallis test was used o access differences between groups in the different moments.

When we compared CG and the SA groups, we did not found again any statistically differences in all times of evaluation (Figure 26). However, the difference of PT/BW values between T0 and T4 moments of the SA group was of -8,17%, showing the largest decrease of PT/BW values comparing with the VA and the CG groups.

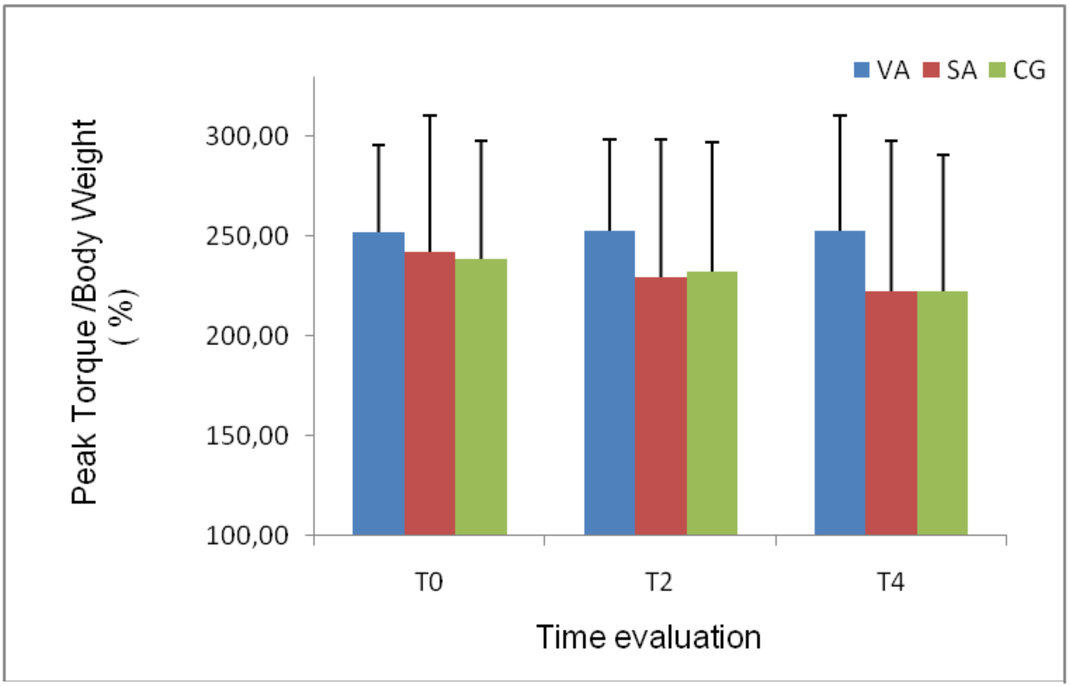


Figure 26 - PT/BW scores of the VA, SA and CG groups (mean ±SD).

When we compared the VA and the SA groups, we didn´t find a statistically differences in all times of evaluation.

Average Peak Torque

The VA and SA groups didn´t showed any significant changes in AVG PT scores along T0 to T4 assessment times (Table 13), while the CG group showed. It´s important to note that CG and SA showed a constant decrease of PT/BW along the time, while the VA group showed a little increase. However, when we compared the different groups in the different moments we observed a not statistically significant difference in AVG PT at all assessment times, when we compared all 3 groups.

Table 13.Differences within and between the groups (VA, SA and CG) in the different moments in AVG PT (N.m).

VA	mean ±SD	p within the group	SA	mean ±SD	p within the group	CG	mean ±SD	p within the group	p between groups
T0	151,58 ± 44,08	0,207	T0	157,54 ± 50,41	0,936	T0	143,24 ± 51,00	0,038	0,545
T2	153,83 ± 43,30		T2	145,89 ± 51,90		T2	147,48 ± 61,11		0,826
T4	156,81 ± 48,69		T4	130,45 ± 58,91		T4	132,37 ± 55,79		0,252

VA (Verum Acupuncture Group) SA (Sham Acupuncture Group) CG (Control Group).Values expressed as mean ± standard deviation. The Friedman test with a Bonferroni post-hoc test was used for access differences between the different moments for a specific group. The Kruskal-Wallis test was used o access differences between groups in the different moments.

A group by group analysis in the different moment's didn´t showed any significant differences in AVG PT at T1 through T4 assessment times (Figure 27). However, the VA group showed an improvement of 3,45% of the PT/BW values between T0 and T4, while the CG group showed a decrease of -7,59% of the AVG PT values between T0 and T4.

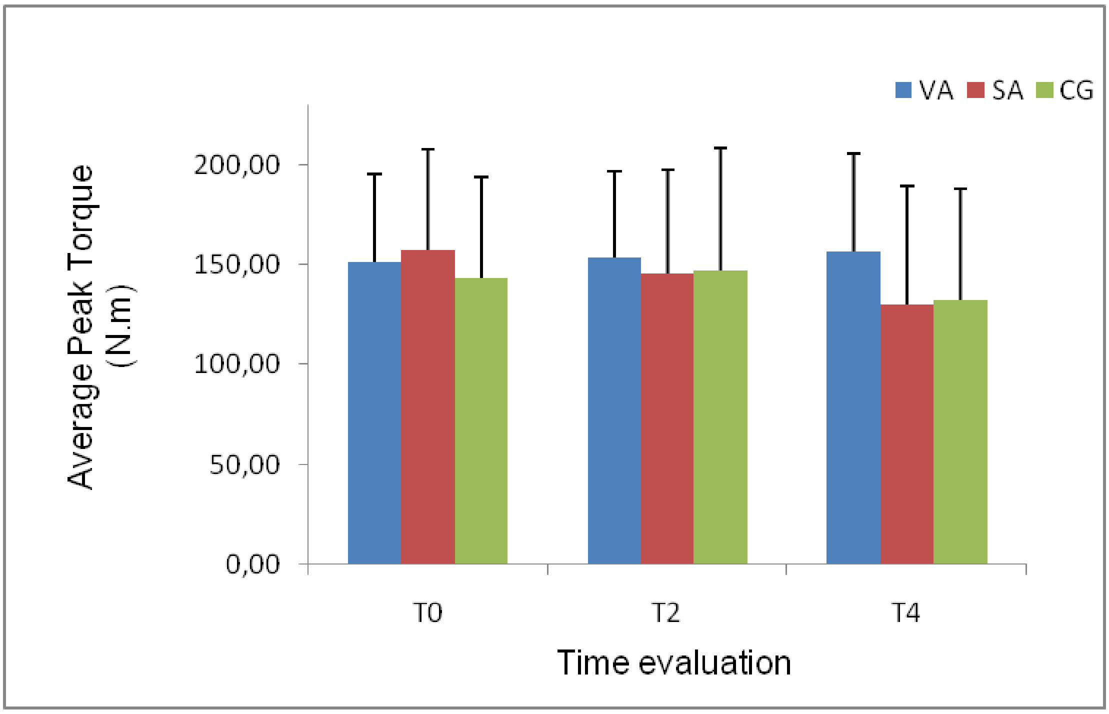


Figure 27 - AVG PT scores of the VA, SA and CG groups (mean ±SD).

When we compared CG and the SA groups, we didn´t found again statistically differences in all times of evaluation. Nevertheless, the difference between T0 and T4 moments of the SA group AVG PT values was of -17,19%, showing the largest decrease of AVG PT values, comparing with the other two groups.

When we compared the VA and the SA groups, we didn´t find a statistically differences in all times of evaluation. However, we found that in the VA we see a progressive increase in AVG PT from an mean initial value (T0) of 151,58 N.m to a final value of 156,81 N.m (T4), the SA and VA groups showed a decrease in at all times, suggesting an immediate and a more long term effect of acupuncture.

Table 14.Differences between the groups (VA, SA and CG) in the different moments in AVG PT (N.m).

VA vs. SA	p between VA vs. SA	VA vs. CG	p between VA vs. CG	CG vs. SA	p between CG vs. SA
T0	0,820	T0	0,319	T0	0,373
T2	0,724	T2	0,520	T2	0,852
T4	0,221	T4	0,101	T4	0,820

VA (Verum Acupuncture Group) SA(Sham Acupuncture Group) CG (Control Group).The Kruskal-Wallis test was used o access differences between groups in the different moments.

Chapter 4 - Discussion

Discussion

On recent literature, the few studies referring acupuncture effects on DOMS, present controversial results, and this fact might occur due to, largely, the different kind of methodologies used on those studies. However, the acupuncture duration, it´s type and the number of used points, muscular groups in which it was applied, the model of EIMD, and respective intensity, as good as the evaluator experience, varies a lot among acupuncture studies (Barroso et al., 2010; Barroso et al., 2011; Lin and Yang, 1999; Barlas et al., 2000; Hübscher et al, 2008; Itoh et al., 2008).

Therefore, in this study, it was sought to examine what's the acupuncture effect on DOMS on the immediate time and 24 hours after the realization of an EIMD protocol, as well as, if there are differences when using the same technique in verum points or sham points.

The exercise bout was successful in inducing muscle damage, which was evident from the significant change of variables and concurs with previous literature that reported similar trends following a like mode of exercise (Miyama and Nosaka, 2004a; Goodall and Howatson, 2008; Howatson et al., 2012). The PPT and muscle strength (PT/BW) were used, as they were the two best markers of muscular damage and the most often used (Torres et al., 2012). In fact, according to some authors, muscle strength might be the most relevant marker of muscle damage (Warren et al., 1999; Morton, et al., 2005). Many authors evaluate also MS, ROM and VJ (Miyama and Nosaka, 2004a; Goodall and Howatson, 2008; Howatson et al., 2012, Jay et al., 2014), precisely corresponding to the variables analysed in this study as indirect markers of muscular damage.

MS and PPT

Available experimental evidence does not consistently support acupuncture as a method for pain relief (Chapman et al, 1980; Brockhaus, Elger, 1990). Past studies were flawed in experimental design, sample size or control. In some randomized controlled trials of acupuncture, control groups were defined as non-treatment controls (Coan, Wong, Coan, 1982) pricking (without penetration) (Johansson et al, 1991), minimal acupuncture (shallow and weak needling) (Vincent, 1989) and mock TENS (without pulse) (Petrie, Hazleman,1986; Streitberger, Kleinhenz, 1998). Moreover, negative results tended to come from studies using non-tender point acupuncture (Barlas et al., 2000) and positive results from studies using non-acupuncture control groups (Lin, Yang, 1999). We used non-treatment controls and non-tender point acupuncture in this study. Non-tender point acupuncture has been proposed as a sham technique (Vincent, Lewith, 1995; Richardson, Vincent, 1986), which is problematic due to the existence of diffuse noxious inhibitory controls phenomena. Painful stimulation inhibits pain, and diffuse noxious inhibitory controls have been proposed as a physiological basis of acupuncture analgesia (Nabeta, Kawakita, 2002; Bing, Villanueva, Le Bars, 1990).

In spite of the results shown above, recent research provides evidence for the efficacy of acupuncture on pain and dysfunction in various musculoskeletal and inflammatory disorders (Brinkhaus et al., 2006; Irnich et al., 2003; Tam et al., 2007). It is conceivable that acupuncture could also be a potential treatment option in DOMS. However, there is no consistent evidence to support this hypothesis.

In this study, was shown that DOMS worsens the MS and PPT values like literature refers (Miyama and Nosaka, 2004a; Goodall and Howatson, 2008; Howatson et al., 2012, Jay et al., 2014). It was also found that VA shown to reduce MS through VAS and improve PPT values, immediately and 24 hours after EIMD.

It is important to point out that the VA results were statistically significant better than the ones of the SA and the CG in PPT and than those of the CG group in MS outcome values. In spite of not being statistically significant better than the SA group values in MS, VA MS values were better than the SA group MS values, especially when MS values were compared between T0 and T4. These facts might suggest that acupuncture might be a factor to take into account on DOMS, especially in MS pain with without pressure.

Itoh et al. (2008) corroborates the results of this study showing significant differences in VAS for pain between the control group and acupuncture group immediately after treatment and three days after exercise ($p<0{,}05$, for Dunnetts multiple test). In the investigation of Hübscher et al (2008), there were no significant differences between groups in outcome measures at the baseline (T0). After 72 hours, muscle soreness was significantly lower in the acupuncture group compared to the sham acupuncture and control subjects. However, the mean PPT scores were not significantly different between groups. Another study which had similar results to the present study, Lin and Yang (1999) demonstrated significant reductions in muscle tenderness through acupuncture versus no acupuncture, whereas CK activity remained unchanged. These results could not be confirmed in a study by Barlas et al. (2000), who reported insignificant changes in tenderness and perceived muscle soreness when acupuncture was compared to sham acupuncture and no acupuncture. In addition, these last two studies did not include any measures of muscle function that might be, besides muscle soreness, tenderness, and inflammation, considered an important outcome when the objective is to appraise the efficacy of acupuncture in DOMS.

These results may be of notable interest in athletic health care delivery since scientific evidence suggests that pain may cause alterations to neuromuscular joint control and joint kinematics (Cheung, 2003). These compensatory mechanisms may provoke, besides impaired muscular performance, a reduced training capacity and may increase the risk of further injury (Cheung, 2003). However, the question whether acupuncture induced pain reductions in DOMS could have beneficial effects on training capacity, long-term competition performance and incidence of sports injuries should be addressed in further studies. These positive results in MS and PPT values, observed in this study, in the SA group and especially in the VA group can be explained because acupuncture promotes local healing as it can be seen in local effects, by stimulating nerve fibers in skin and muscle. These sensory nerves form a network in the layers of the skin. Needling one of these nerves sets off action potentials. The action potentials spread around the network locally, an effect that is known as an 'axon reflex'. Various substances are released as a result, particularly one, called calcitonin gene-related peptide. This causes the local blood vessels to dilate, so the local blood flow increases. This effect can often be seen in patients having acupuncture: the skin around the needles often flushes bright red with the increased blood flow and afterwards a small 'weal' can be seen under the skin. The blood flow is also increased in the deeper tissues, which encourages tissue healing, for example in some skin conditions or minor injuries. It may also improve the function of local glands, such as salivary glands (White, Filshie, Cummings, 2008).

Because of that, in this study were applied local needles. Another way to justify the results of this investigation on MS and PPT values, is the other effect of acupuncture: segmental analgesia. Acupuncture reduces pain in the segment where the needles are inserted because the action potentials also travel up the nerve directly to its particular segment in the spinal cord where they tend to depress the activity of the dorsal horn, reducing its response to painful stimuli. This is known as a 'segmental' effect, and is probably the main mechanism by which acupuncture relieves pain – the symptom it is most commonly used for. Acupuncture inhibits pain from any part of the body which sends nerves to that particular segment of the spinal cord. For example, the nerves from a painful knee joint enter the same segment as the nerves from the muscles around it: so pain in the knee joint will be reduced by needles inserted in those muscles. Actually, because the connections of the nerves are not confined precisely to a single segment, the segmental effect of acupuncture spreads to the adjacent segments as well (White, Filshie, Cummings, 2008). Possibly because of that, VA and SA groups had better results than CG group.

On a clinical trial carried out by Brinkhaus, et al (2006) under a project started by the German Federal Committee of Physicians and Health Insurance, in order to investigate the acupuncture effectiveness when compared with sham acupuncture, the authors concluded that there were evidence that the sham acupuncture intervention can't be considered a placebo, since it isn't physiologically inert and has specific analgesic effects. Such fact is also supported by this study where it was evident that the SA values was better than the CG group values in MS and PPT, in spite of not being statistically significant. Pomeranz (1996) suggests a common mechanism underlying real and sham acupuncture which can focus on pain, from its origin, transmission or pain signals processing on the central nervous system, and may be one of the likely reasons for such scores.

The findings can raise some uproar about limitations that may exist regarding acupuncture action. However, it should be stressed that acupuncture, as a part of the TCM body of knowledge, aims to normalize vegetative changes, reestablish “Qi” and “Xue” circulation on the conduct level, organs and viscera and, therefore, helps the body to reestablish its neurovegetative operation (Yamamura, 1993; Greten, 2010).

As TCM views DOMS as localized “Qi” and “Xue” stasis that manifests as pain and soreness of the muscles or tendons, the “leopard spot” technique was a very important technique because it disperses “Qi” and “Xue” stasis. The TCM attributes the muscle damage on hepatic “Qi” stasis leading to hepatic Yin or hepatic “Xue” deficiency, so, H3 was used in this study because is good against constriction of the conduit system and is an Inductorium of the hepatic conduit-Earth point (orthopathy) on a wood conduit-potential, i.e. brings eu regulation to the potential, is a point of hepatic “Qi” originale (stabilizes and regulates hepatic and the felleal orb), regulating and reducing the excess activity of “Xue” (Greten, 2010).

Another point used in this study was S34 because is a "rimicum" point on the conduit of the Stomach and the “rimicum” points are essential to treat Bi syndromes, as in DOMS. This term arises due to the ability of the rimic points to infuse dynamic “Qi” along the conduit when, for some reason, there arises congestion or “Qi” stasis (Porkert, Hempen and Pao, 1995; Hempen, Chow, 2006). Thus, the S34 plays an important role, particularly in pain management throughout the conduit (Greten, 2010).

In this study was used S36, which is a conjunctorium of the Stomach conduit- Earth point on Earth conduit, it regulates the relation between the vegetative capacity to function (“Qi”) and the functional capacity bond to the body fluids (“Xue”), Eu-regulation: stabilizes the Centre (Stomachal and Lienal orb) and acts in all forms of hidrostasis *Humor* (Greten, 2010).

In the point of view of TCM, the “leopard spot” technique is indicated to treat DOMS, but it has also an explanation in a western point of view, because this technique increase the blood flux on muscular level with the purpose of decreasing the generated pain by metabolic final products (Shinbara, et al., 2008), one of the possible causes of DOMS and on the presence of *algor* patterns, decreasing of the capillary perfusion and inflammation, another of DOMS etiological factors (Doenitz et al., 2012).

By decrease blood pressure (Hou jinglun, 1995) this technique could, at least in theory, alleviate some of the symptoms attributed to the increase in hydrostatic pressure seen in DOMS.

ROM

Despite the absence of the use of ROM in recent acupuncture studies on DOMS (Lin and Yang, 1999; Itoh et al., 2008; Hübscher et al, 2008), ROM was used in this study because some studies show that after EIMD, ROM decreases (Miyama and Nosaka, 2004a; Goodall and Howatson, 2008; Howatson et al., 2012, Jay et al., 2014). This study confirms these findings because ROM decreased in all groups (VA, SA and CG). However, VA group reduced this decrease of ROM more than the others, but not in a statistically significant form. Barlas et al. (2000), had the same results in their study, also with no statistically significant differences between groups.

VJ, PT/BW and AVG PT

On the literature there are several evidences that show the acupuncture effectiveness on the increase of muscular power (Huang, et al., 2007; Hubscher, et al., 2010; Ozerkan, et al., 2007; Yang, et al., 2006; Zhou, et al., 2012). However, regarding VJ, some demonstrate controversial results when compared to the results in this study. As an example, Banzer et al. (2007) on a study made with 12 sports students with the purpose of testing the acute effects of acupuncture on physical performance, the authors didn't noticed significant changes on VJ performance after one acupuncture session. The same results were noticed by Hubcher et al. (2010) on a similar study. These authors (Banzer, et al., 2007; Hubscher, et al., 2010) used the "drop jump" test on one foot (Banzer, et al., 2007) and two feet support (Hubscher, et al., 2010) to measure the explosive power of vertical impulse. However, the utilization of this performance test, in non-athletes (Banzer, et al., 2007) or athletes with a low competitive level (Hubscher, et al., 2010), allied with a lack of experience on the intended gesture and reduced sampling, might explain the different results found since that it is a less functional test and it requires a high coordination and familiarization from the participants. Curiously, both of the above cited studies (Banzer, et al., 2007; Hubscher, et al., 2010) applied a similar acupuncture protocol, using the same acupuncture points, suggesting that the selection of acupuncture points according to it´s specificity plays an important role to achieve the intended results (Choi, Jiang and Longhurst, 2012; Parrish, et al., 2005). Therefore, while these authors have verified a tendency to increase muscular recruitment (Banzer, et al., 2007) and isometric power (Hubscher, et al., 2010), this protocol wasn't seemed as the most adequate one to induce changes at the vertical impulsion level.

In this sense, some authors (Bobbert, and Van Soest, 1994; Herrero, et al., 2006) defend that the isolated increase of muscular power only reflects itself on VJ performance, after a training period under those muscular conditions, therefore reestablishing the great motor coordination (muscular activation) and consequent performance. However, the present study showed (not statistically significant in PT/BW and AVG PT, but statistically significant in VJ) the capacity of an acupuncture protocol to increase muscular power or more correctly to avoid a decrease in muscle performance when performing a functional task like a VJ.

There are some studies that show that after EIMD, muscle power decreases (Miyama and Nosaka, 2004a; Goodall and Howatson, 2008; Howatson et al. 2012, Jay et al. 2014). This study confirms these findings because VJ decreased in all groups (VA, SA and CG) as all other muscle power measurements (PT/BW and AVG PT). It´s important to note that VA group had statistically significant better results than CG group in VJ measures. These results are in line with the study by Sousa (2012), where in VA group at the point S34 with the same technique used in this study, had better results in increased vertical jump in volleyball players than a SA group. The authors concluded that VA group significantly improved the VJ, while in the SA group, there was a slight loss of vertical jump.

However, the ability to produce power comes from the nervous system capacity to activate the muscles effectively and coordinately through the motor unities recruitment and/ or discharge pulses (Komi, 2003) and considering that the acupuncture is a reflexive therapy that involves local, central and vegetative mechanisms this is one possible explanation. There is a lack of consensus in the literature regarding the acupuncture effects on motoneurons excitability, particularly alpha motoneurons (Chan, Vujnovich, and Bradnam-Roberts, 2004; Fink, et al., 2004). In this sense, the alfa motoneurons stimulus increase on quadriceps may result on a bigger excitability or recruitment of muscle motor unities, which may explain the documented increase of explosive power in VJ and the results of PT/BW and AVG PT.

The use of S34, S36 and H3 which promotes the “Qi” flux, throughout the stomach conduct (earth), harmonizing and regulating the function of all the other orbs by using the “leopard spot” technique potentiates the “Qi” and “Xue” flux throughout the conduct, favoring a more efficient muscular contraction and recovery.

Another mechanism that may, additionally, have contributed to the obtained results, was the increase of microcirculation and the transportation of O_2 to the different tissues induced by acupuncture (Doenitz, et al., 2012; Shinbara, et al., 2008; Zheng, et al., 2012). Zheng et al. (2012), on a study of the influence of acupuncture on blood perfusion, suggests that the stimulation of only one point of the stomach conduct, may increase subcutaneous microcirculation in adjacent points through the conduct.

We cannot fail to mention that anatomic localization of S34 point is related with a “trigger point” on the quadriceps vastus lateralis muscle. Other contemporary techniques contemplate that this point manipulation results on an improved dynamic balance improvement of the knee promoting a better muscular performance (Ma, 2011).

Although the physiologic mechanisms inducing the beneficial effects of acupuncture on perceived pain on DOMS need further clarification, it may be explained by the central neurobiological mechanisms of acupuncture analgesia. In this context, acupuncture has been shown improve microcirculation (Kuo, Lin, Ho, 2004) to decrease inflammatory processes (Moon et al, 2007) to release endogenous endorphins (Hwang et al, 2002), to modulate sympathetic nerve activity (Huang et al, 2005), to alter cerebral activation (Biella et al, 2001), to inhibit spinal and supraspinal nociceptive transmission (Ikeda, Asai, Murase, 2000; Rong et al, 2005), as well as to activate signal transduction pathways through a mechanical coupling between the needle and connective tissue (Langevin, Churchill, Cipolla, 2001).

Beyond the impact on the outcome measures, the “leopard spot” technique on the points S34, S36 and H3 proved to be a rapid execution technique (2 minutes), easy to administrate, low cost and without adverse effects with the exception of a minor bleeding (without any specific treatment). However, although the technique and points used on this study have been selected according to TCM theory, it is important to refer that the acupuncture points selection based on an individual TCM diagnostic, or, in other words, to determine the actual neurovegetative state, might potentiate or drastically maximize the acupuncture effects (Greten, 2010; Park, et al., 2008; Porkert, 1983).

Therefore, the results obtained on this study might represent just a small sample of the acupuncture effectiveness on DOMS.

Acupuncture, namely the one that is administrated according to an individualized functional diagnostic, may be an effective and beneficial treatment strategy on the therapeutic approach, also on the identification and early treatment for DOMS and other pathologies. A rational view of TCM on an acceptable academic level is still relatively hard to get, however, it has been collected older data with new archeological findings that are known, justifying TCM as a logic model of biological systems based on a mathematic language, according to the interpretation of the Heidelberg Model. When some research is made in this area, it must be taken into account the concept of point specificity. This concept maintains that different physiological and clinical answers result from stimulation of different acupuncture points. On the practice of acupuncture, success strongly comes from the capacity to stimulate the better combination of acupuncture points for a certain condition, which is only possible after a correct diagnostic.

Limitations and suggestions

One of the limitations of this study was that the sample was reduced. Another was that only participants were only "blinded" to the intervention. In order to further minimize possible placebo effects inherent to the acupuncture technique used, researchers should remain "Blind". However, all efforts to ensure that participants receive the same contact and verbal stimulation by the researcher were performed. Another limitation of the study was that DOMS was only evaluated immediately and 24 hours after the EIMD. Further studies are suggested with similar methodologies and EIMD protocol, acupuncture technique, muscle group and assessment methods but with a bigger sample, “blind” researchers and also an increased timeline, 24h, 48h and 72h after EIMD and include biomarkers (e.g. CK, Myoglobin, inflammatory markers).

Another suggestion would be to check whether acupuncture has beneficial effects applied before EIMD protocol, to promote the prevention of DOMS.

With these good results in non athletes, it is suggested a future research in order to examine the effectiveness of acupuncture in a routine athletic care setting.

Chapter 5 - Conclusions

Conclusions

The general consensus says that DOMS is a combination of several mechanisms beginning with micro-trauma of muscles and connective tissues which is followed by an inflammatory process and edema. TCM views DOMS as a localized “Qi” and “Xue” stasis that manifests as pain and soreness of the muscles or tendons.

Acupuncture has been studied as a treatment for many causes of pain, being a promising treatment for DOMS because it showed that can reduce MS and improve PPT and VJ, yet with limited results in muscular power and ROM.

When VA, SA and CG groups were compared, it was found that VA had better results in all outcome measures, especially in MS, PPT and VJ. However, SA group showed better results than CG, when MS and PPT were compared, but they were not statistically significant.

The protocol of EIMD showed success in inducing DOMS and future studies are needed for a better comprehension of DOMS mechanisms and treatment.

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Annex A - Questionnaire

Questionário para selecção da amostra

Questionário nº__

Questionário

Este questionário foi elaborado pelo estudante de mestrado Ricardo Cardoso, sob a orientação do Prof. Dr. Henry Greten e coorientação pelo Prof. Dr. José Lumini Oliveira no âmbito do Mestrado em Medicina Tradicional Chinesa e tem como finalidade permitir seleção de participantes para a realização de um estudo cujo tema é "Acupuncture effects on Delayed Onset Muscle Soreness".
A informação recolhida jamais servirá para outros fins que não esta investigação sendo que os dados obtidos serão anónimos e confidenciais.
Instruções de preenchimento
As opções devem ser seleccionadas com uma **cruz (X),** no quadrado respectivo. Nas questões abertas, responda nas linhas disponíveis.

Dados Pessoais:

Nome (primeiro e último): ____

Data de nascimento: ___ / ___ /____

Contactos: Telemóvel:_______________Email:______________________________

1. Pratica alguma modalidade desportiva? Sim □ Não □

Nota: Se respondeu sim, o seu questionário termina aqui. Obrigado pela sua colaboração.

2. É portador de alguma patologia cardíaca e/ou renal? Sim □ Não □

Nota: Se respondeu sim, o seu questionário termina aqui. Obrigado pela sua colaboração.

3. Tem ou teve recentemente:

3.1) Lesão muscular ou tendinosa na coxa □

3.2) Lesão ligamentar no joelho ou tornozelo □

3.3) Lesão meniscal no joelho □

3.4) Dor na coxa e/ou joelho □

3.5) Outras patologias que o impeçam de fazer actividade física □ Qual/Quais?

____

4. Está a fazer medicação com anti-inflamatórios? Sim □ Não □
Se respondeu sim, qual o fármaco utilizado?

____

5. Tem alguma outra informação que entenda ser importante e não tenha ainda sido referida neste questionário? Se sim, qual?

____
____
____
____
____

Muito obrigado pela sua participação

Anexx B – Informed Consent

Declaração de Consentimento

Considerando a “Declaração de Helsínquia” da Associação Médica Mundial (Helsínquia 1964; Tóquio 1975; Veneza 1983; Hong Kong 1989; Somerset West 1996 e Edimburgo 2000)

Designação do Estudo

O nosso projecto intitula-se “Acupuncture effects on Delayed Onset Muscle Soreness”, e consiste na aplicação de acupunctura para reduzir os efeitos da sensação retardada de desconforto muscular com o intuito de avaliar a eficácia da acupunctura através da utilização da percepção de desconforto à pressão, amplitude articular, salto vertical, força muscular e da escala visual analógica. Neste contexto venho solicitar a vossa Exma. a sua participação no preenchimento do seguinte questionário. A informação recolhida será anónima e confidencial e apenas utilizada exclusivamente para o presente estudo, pelo que não se deve identificar ao longo do mesmo salvaguardando desta forma a sua privacidade.

Eu, abaixo-assinado, (nome completo) ____

________________________, compreendi a explicação que me foi fornecida acerca da minha participação na investigação que se tenciona realizar, bem como no estudo em que serei incluído. Foi-me dada oportunidade de fazer as perguntas que julguei necessárias e de todas obtive respostas satisfatórias.

Tomei conhecimento de que, de acordo com as recomendações da Declaração de Helsínquia, a informação ou explicação que me foi prestada versou os objectivos e os métodos. Alem disso, foi-me afirmado que tenho o direito de recusar a todo o tempo a minha participação no estudo, sem que isso possa ter como efeito qualquer prejuízo pessoal.

Por isso consinto que me seja realizado o estudo em questão.

Data: ___ /___/______

Assinatura do inquirido: _____________________________

O Investigador Responsável: ______________________

Annex C - Authorization of the Director of Hospital-School of Fernando Pessoa University and the department chief of the Physical Medicine and Rehabilitation department.

“Exmo. Terapeuta Ricardo Cardoso.

Em nome da direção clínica, venho, por este meio, e à luz da informação inframencionada, autorizar o envio da documentação completa para análise final do projeto pela Comissão de Ética, sabendo que aqui, no Hospital-Escola, terá sobre supervisão de uma médica vocacionada para Acupunctura, na Unidade de Medicina Física e Reabilitação- Dra. Joana Almeida - onde se encontra o T. Ricardo:

Em anexo as Normas de Boas Práticas em Acupunctura Médica, estabelecidas pelo Departamento da Qualidade e Saúde da DGS e OM e publicadas pela Sociedade Portuguesa Médica de Acupunctura.
Quanto à legislação em vigor:
DL 500/99 de 19 de Novembro: aprova o regime jurídico do licenciamento e fiscalização do exercício da actividade das clínicas privadas de MFR. A Acupunctura insere-se no art. 1º, alínea 2 - Outras Técnicas Terapêuticas. Art. 6º e Art. 7º definem as normas de qualidade e segurança definidas pelo código científico e técnico internacionalmente reconhecidos nesta área e o manual de boas práticas (acima mencionado) aprovado pelo Ministério da Saúde, ouvidas a OM e a CTN.

Boas_Práticas_Acupunctura_Médica.pdf
440 KB

1. **Os estudos existentes parecem confirmar que a maioria dos efeitos adversos graves e mortais surgem no Mundo Oriental e/ou quando a acupunctura é realizada fora de contextos Médicos**.
Referencias: "A cumulative review of the range and incidence of significant adverse events associated with acupuncture", Adrian White. Acupuncture in Medicine 2004; 22(3):122-133
"Overview: Adverse events of acupuncture", James K. Rotchford MD. Medical Acupuncture. Falo 1999/Winter 2000 - volume 11/ number 2

2. **Nos estudos prospectivos abrangendo exclusivamente Profissionais de Saúde não surgiram quaisquer efeitos adversos graves.**
Referencias: "Survey of adverse events following acupuncture (SAFA): a prospective study of 32,000 consultations". Adrian White, Simon Hayboe, Anna Hart, Edzard Ernest. Acupuncture in Medicine 2001; 19(2):84-92
"A prospective Survey of adverse events and treatment reactions following 34,000 consultations with Prof. Acupuncturists". Hugh MacPherson, Kate Thomas, Ste. Walthers, Mike Fitter. Acupuncture in Medicine 2001; 19(2):93-102

Com os melhores cumprimentos,

--
Pela Direção Clínica
Isabel Santos”

Annex D - Ethics Approval

Universidade Fernando Pessoa
www.ufp.pt

Aluno nº 17983

Exmo. Senhor
Prof. Doutor Luís Martins
Diretor da FCS

Porto, 26 de Março de 2014

Exmo. Senhor Prof. Doutor,

A Comissão de Ética, depois de apreciado o projeto de Mestrado em Fisioterapia, de Ricardo Manuel Tavares Cardoso, intitulado "Acupuncture effects on Delay Onset Muscle Soreness", considera nada haver a opor ao mesmo.

Com os melhores cumprimentos.

A Vice-Presidente da
Comissão de Ética

Teresa Martinho Toldy

Comunicar ao mestrando

Fundação Ensino e Cultura "Fernando Pessoa"
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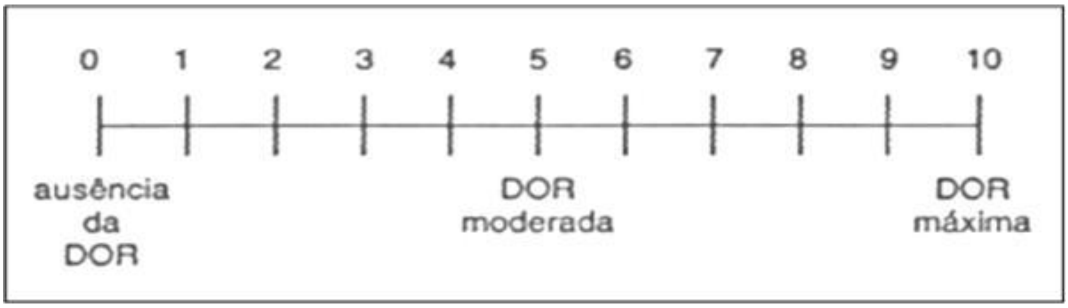
Anexx E - Visual Analogue Scale



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